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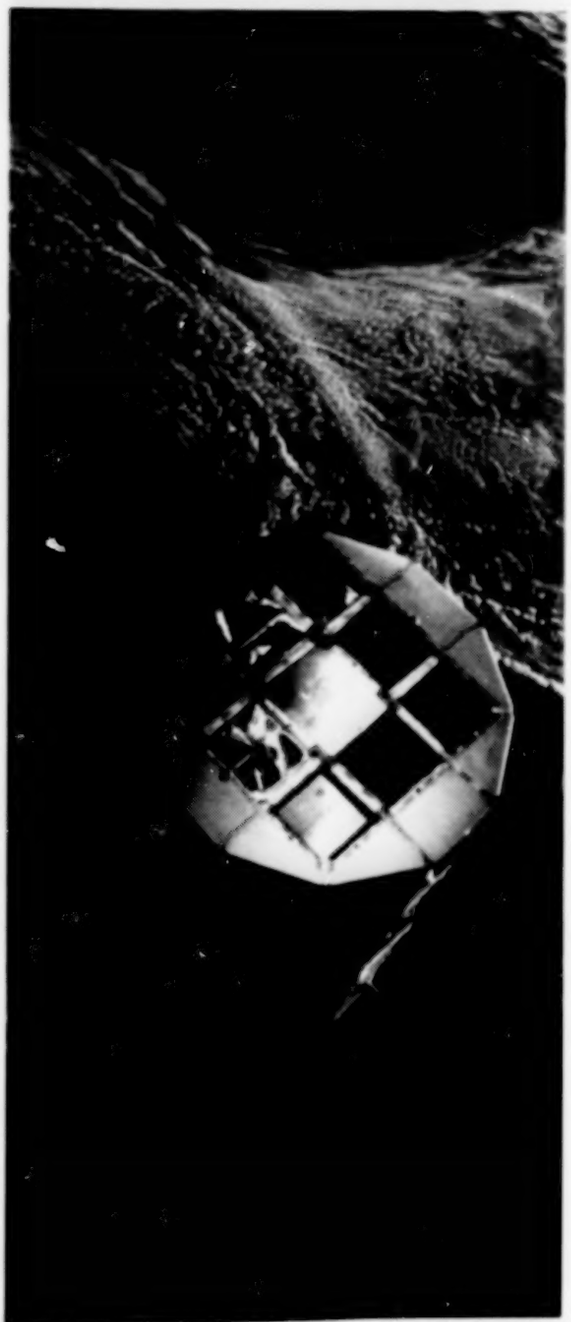

First LDEF Post-Retrieval Symposium Abstracts

June 2-8, 1991

Sponsor: LDEF Science Office

NASA Langley Research Center

Hyatt Orlando

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PREFACE

The Long Duration Exposure Facility (LDEF) was retrieved from orbit by the Shuttle *Columbia* on January 12, 1990, after it had spent almost 6 years in space. The LDEF and 57 onboard experiments, which involved more than 10,000 spacecraft material and systems test specimens, were designed to help scientists and engineers better understand the environments of space and the effects of prolonged exposure in these environments on future spacecraft such as Space Station *Freedom.*

The experiment principal investigators and the investigators in four special investigative groups (meteoroids and debris, ionizing radiation, materials, and systems) have studied the retrieved LDEF hardware and experiment test specimens for approximately a year. Also, 3,500,000 students have observed the growth of 13,000,000 tomato seeds that flew on the LDEF.

The results of the first year of studies will be addressed at the First LDEF Post-Retrieval Symposium (June 2-8, 1991, in Kissimmee, Florida). This document contains abstracts of the first symposium papers. These abstracts are organized according to the symposium agenda into five sessions. The first session provides an overview of the LDEF, the experiments, the mission, and the natural and induced environments the spacecraft and experiments encountered during the mission. The second session presents results to date from investigations to better define the environments of near-Earth space. The third session addresses studies of the effects of the space environments on spacecraft materials. The fourth session addresses studies of the effects of the space environments on spacecraft systems. The fifth session addresses other subjects such as the results of the LDEF life science and crystal growth experiments.

Most of the studies reported at the first symposium and addressed in these abstracts will continue for two more years. Second and third symposia are planned to continue reporting the results during each of these years.

The post-retrieval LDEF investigations and the LDEF symposia are managed and coordinated by the LDEF Science Office at the NASA Langley Research Center. For additional information on this symposium, or future symposia, please contact:

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THE ROLE OF THE LONG DURATION EXPOSURE FACILITY IN THE DEVELOPMENT OF SPACE SYSTEMS: SPACE STATION AS CASE-IN-POINT

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ABSTRACT

The Long Duration Exposure Facility (LDEF) presents the international, aerospace community with an unprecedented opportunity to examine synergistic, long-term, space environmental effects on systems and materials. This paper explores the potential contribution of its analysis to future space systems, utilizing examples from the Space Station *Freedom* as a case-in-point. Fundamental to the LDEF's role as a space system, a space experiment, and a "treasure trove" of valuable information for spacecraft developers and users, such as the Space Station *Freedom*, is the following acknowledgment:

> Obtaining long-term space exposures and the analysis of the data within appropriate environmental contexts are essential to the overall process of advancing the understanding of space environmental effects which, in turn, is needed for the continuing development of strategies to improve the reliability and durability of space systems and to effectively deal with the future challenges that new space initiatives will likely present.

This relationship is explored viewing the LDEF and its mission as a microcosm of the long-term space exposure to be experienced by a broad spectrum of current and future space systems, including Space Station *Freedom*. Such a perspective inherently reveals the need for persistent, on-going effects to obtain new space exposures of long duration, and to expand fundamental understanding of the complexities of the multi-faceted space environments, their efforts, and how we can more effectively utilize them.

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LDEF MISSION

AND

INDUCED ENVIRONMENTS

OVERVIEW

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ABSTRACT

The Long Duration Exposure Facility (LDEF) is a 12-sided, 15-foot in diameter, 30-foot long aluminum frame, designed and built at the NASA Langley Research Center in Hampton, Virginia. Fifty-seven (57) science, applications and technology experiments were stored in trays, fixed to the aluminum frame and flown in space for 68 months. (See table below for a list of experiments.)

Crystal Growth	Trapped-Proton Energy Spectrum
Atomic Oxygen Outgassing	Heavy Cosmic Ray Nuclei
Atomic Oxygen Interaction	Lineary Energy Transfer Spectrum
High-Toughness Graphite Epoxy	Microabrasion Package
Radar Phased-Array Antenna	Meteroid Impact Craters
Composite Materials For Space Structures	Dust Debris Collection
Epoxy Matrix Composites	Chemistry Of Micrometeoroids
Composite Materials	Measurements Of Micrometeoroids
Metallic Materials Under Ultravacuum	Interplanetary Dust
Graphite-Polymide And Graphite-Epoxy	Space Debris Impact
Spacecraft Materials	Biostack
Balloon Materials Degradation	Seeds In Space
Thermal Control Coatings	Student Seeds Experiment
Spacecraft Coatings	Holographic Data Storage Crystals
Thermal Control Surfaces	Infrared Multilayer Filters
Textured And Coated Surfaces	Pyroelectric Infrared Detectors
Variable Conductance Heat Pipe	Metal Film And Multilayers
Low-Temperature Heat Pipe	Vacuum-Deposited Optical Coatings
Transverse Flat-Plate Heat Pipe	Ruled And Holographic Gratings
Thermal Measurements	Optical Fibers And Components
High Voltage Drainage	ERB Experiment Components
Solar Array Materials	Solar Radiation On Glasses
Advanced Photovoltaics	Quartz Crystal Oscillators
Coatings And Solar Cells	Active Optical System Components
Solid Rocket Materials	Fiber Optic Data Transmission
Interstellar Gas	Fiber Optics Systems
Ultra-Heavy Cosmic Ray Nuclei	Space Environments Effects
Heavy Ions	

This paper will provide a description of the concept development, prelaunch integration, flight mission, and postretrieval deintegration of the LDEF.

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LDEF ATTITUDE MEASUREMENT USING A PINHOLE CAMERA WITH A SILVER/OXYGEN ATOM DETECTOR

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ABSTRACT

The University of Alabama in Huntsville experiment A0114 entitled "The Interaction of Atomic Oxygen with Surfaces at Orbital Attitude" carried a small device designed to measure the orbital attitude-stability of the LDEF spacecraft. The device used the reaction of silver with oxygen atoms, which convert the metal to a non-conducting black-appearing oxide with high efficiency. The atmosphere at LDEF altitudes consists of more than 90% atomic oxygen. The device is a small hemispherical silver surface facing a pinhole in a metal plate on the front surface of the satellite. It was expected that the stream of O atoms, travelling at a relative velocity of 8 $km\text{-}^{1}s$ would pass through the pinhole and strike the silver surface at the geometric center, producing a circular black spot. In fact, the position of the spot has clearly shown that the LDEF was rotated by 8.0 ± 0.4 deg from its nominal attitude, but that it was remarkably stable about this offset. The ellipticity of the recorded spot was attributed to a yaw oscillation of ±0.2 deg, however it was brought to our attention (Bourrassa, 1990) that the co-rotation of the Earth's atmosphere should produce a sweeping of the atom beam vector of ca. ±1.5 deg about the surface normal. Such an effect was not visible in our experiment. We have recently performed calculations of the angular width of the atomic oxygen beam transmitted by an orbiting pinhole including atmospheric co-rotation. These calculations are consistent with our measurement and indicate that the LDEF attitude was even more stable than previously reported.

Experiment No. A0114

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LDEF SPACE ENVIRONMENTS OVERVIEW

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ABSTRACT

The LDEF was launched into an Earth orbit in April of 1984 during a period of minimum solar activity. It was retrieved almost 6 years later in January of 1990 during a period of near maximum solar activity. In flight, the LDEF was passively stabilized in three axes and it flew in a near circular orbit having an inclination of 28.5 degrees and an initial altitude of approximately 257 nautical miles. When the LDEF was retrieved, the orbit had decayed to an altitude of approximately 180 nautical miles. Specifically, the LDEF flew with one surface always facing in the direction of the velocity vector, one surface facing the trailing direction, one surface facing Earth, and one surface facing into space. These facts made the LDEF an ideal platform to expose experiments to investigate the space environments and the effects of these environments on spacecraft materials and systems.

This paper will provide an overview of the specific space environments to which the LDEF experiments were exposed. It will also point out the specific features of the LDEF that allow the effects of different environments to be isolated.

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"USE OF THE LONG DURATION EXPOSURE FACILITY'S THERMAL MEASUREMENT SYSTEM FOR THE VERIFICATION OF THERMAL MODELS"

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ABSTRACT

This paper presents results of the comparison between the Long Duration Exposure Facility (LDEF) Thermal Measurements System (THERM) recorded temperature data and the predicted values as calculated prior to the LDEF deployment. The post-flight thermal model has been verified and calculated temperatures uncertainties have been reduced to under ±18°F from the pre-flight uncertainties of ±40°F. The THERM consisted of eight temperature sensors, a shared tape recorder, a standard LDEF flight battery, and an electronics control box. The temperatures were measured at selected locations on the LDEF structure interior during the first 490 days of flight and recorded for post-flight analysis. After the LDEF retrieval from Space on January 12, 1990, the tape recorder was recovered from the spacecraft and the data reduced for comparison to the LDEF predicted temperatures. The LDEF mission temperatures were calculated prior to the LDEF deployment on April 7, 1980, and updated after the LDEF retrieval with actual flight parameter data; including thermal fluxes, spacecraft attitudes, thermal coatings degradation, and contamination effects. By comparing the calculated values to the measured data, a verified thermal model that presented the best agreement with the THERM data was obtained.

The THERM experiment provided an economical way of performing a post-flight verification of the LDEF Thermal Model by recording a limited number of flight temperatures on typical locations of the LDEF structure. This method of thermal model verification is suitable for spacecrafts where the facility is to be retrieved from space for post-flight study of specimens, and where thermal verification testing cannot be performed due to cost or logistics problems.

Experiment: THERM P0003

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N91-24976

MEASURED SPACE ENVIRONMENTAL EFFECTS TO LDEF DURING RETRIEVAL

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On the STS-32 shuttle mission, a space flight experiment provided an understanding of the effects of the space environment on the Long Duration Exposure Facility (LDEF) from rendezvous with the shuttle until removal from the payload bay at the Orbiter Processing Facility (OPF) at NASA/KSC. The Interim Operational Contamination Monitor (IOCM) is an attached shuttle payload that has been used on two (2) earlier flights (STS 51C and STS 28) to quantify the contamination deposited during the course of the missions.

The IOCM can characterize by direct measurement the deposition of molecular and particulate contamination during any phase of flight. In addition to these principal measurements, the IOCM actively measures the optical property changes of thermal control surfaces by calorimetry, the flux of the ambient atomic oxygen environment, the incident solar flux, and the absolute ambient pressure in the payload bay. The IOCM also provides a structure and sample holders for the exposure of passive material samples to the space environment, e.g., thermal cycling, atomic oxygen, and micrometeoroids and/or orbital debris, etc.

Some of the more salient results from the STS-32 flight suggests that the payload bay was slightly contaminated during both the prelaunch phase of the mission and after the deployment of the SYNCOM IV payload. Both events occurred well before the rendezvous with the LDEF and as such, caused no cross contamination. On the other hand, LDEF acted as a large source of contamination (mainly particulates) to the shuttle. The source emission rate of LDEF averaged 2.5×10^{-12} g/cm^2-sec for a period of eighty hours following berthing, falling off to a rate of 4.1×10^{-13} g/cm^2-sec just prior to re-entry. Post-flight obscuration ratios on IOCM surfaces were 2.4 percent.

The mission atomic oxygen fluence was calculated to be 2×10^{19} atoms/cm^2. Although the fluence is low by normal standards, the Kapton™ passive samples on the IOCM exhibited the onset of erosion. Orbital debris/micrometeoroid impact plates suggest a flux of 6×10^2 impacts/m^2 occurred during the mission, with an average crater diameter of ~12.5 μm. The largest crater diameter was measured at 65 μm.

Measurements during the post-flight phases, i.e., ferry flight and de-integration processing in the OPF, show negligible to very low mass deposition, respectively. The largest mass deposition occurred during the door opening process in the OPF. This paper will provide an in-depth discussion of the results of the data. A complete description of the experiment will also be presented.

N91-24977

MIGRATION AND GENERATION OF CONTAMINANTS FROM LAUNCH THROUGH RECOVERY: LDEF CASE HISTORY

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ABSTRACT

The migration of contaminants to and between LDEF surfaces reveals new information relevant to all future space missions. The surface of the LDEF satellite closely paralleled over seven meters of the shuttle bay surface. It was the ultimate witness plate for the bay of the shuttle during one launch and one reentry. Transfer of contaminants from the shuttle bay to the payload have been documented and partially quantified for both the launch and the recovery separately. LDEF carried a significant burden of volatile silicones and hydrocarbons into orbit which were then polymerized by ultraviolet radiation into tough, dark brown stains on exposed surfaces. The distribution of these stains is providing new information on deposition mechanisms that should be investigated on future missions. Electrostatic effects, diffusional flow, and significant effects due to small surface temperature differences at the time of ultraviolet exposure are suggested. The types of functional groups present in the LDEF deposit is nearly identical to stains recovered from other spacecraft. These stains were remarkably stable in low earth orbit even with atomic oxygen exposure if the amount of silicones present was sufficient to create a sealing layer of silicon dioxide over the dark brown stain beneath. LDEF was not considered a "clean" satellite but evidence from other missions indicate the relevance of what is being learned from a detailed study of its contaminants.

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LDEF CONTAMINANTS ANALYSIS DATA

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ABSTRACT

Modification of Surface Texture for Ram Facing FEP Teflon on the LDEF Satellite is documented. Photos of changes in surface texture if thermal blanket material with position on tray C-08 are presented.

Infrared Spectra and Photographic Documentation of Molecular Film Deposits on LDEF Surfaces by Location is reported. Results of a survey of the functional groups and elemental composition of the brown film found widely distributed on the surface of LDEF will be shown.

A Partial Photographic Catalog of LDEF Particulate Contaminants is included in this paper. A set of photos of particles collected or photographed in place on the surface of LDEF will be shown.

Particle Counts and Surface Obscuration Data for the LDEF Satellite are reported. The surface data in tables and charts is presented for the LDEF satellite by location.

N91-24979

Organic Contamination of LDEF

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A brown stain of varying thickness was present on most of the exterior surface of the retrieved LDEF. Tape lifts of Earth-end LDEF surfaces taken in February 1990 showed that the surface particle cleanliness immediately after retrieval was very good, but faint footprints of the tape strips on the tested surfaces indicated a very faint film was removed by the tape. Solvent wipes of these surfaces showed that the stain was not amenable to standard organic solvent removal. Infrared spectra of optical windows from tray E5 show that the organic film is hydrocarbon in composition, but is not similar to the oil that seeped from tray C12. Very dark and heavy deposits of the stain is present at openings and vents to the interior of LDEF. Heavy brown and blue-green deposits are present in the interior of LDEF where sunlight penetrated through cracks and vent openings. Photographs of the deintegrated LDEF graphically show the stain distribution.

The exterior of LDEF had significant areas painted with a white polyurethane paint for thermal control, and almost all of the interior was painted with a black polyurethane paint for thermal control. The brown staining of LDEF is consistent with long term outgassing of hydrocarbons from these paints followed by rapid solar-ultraviolet-induced polymerization of the outgassed hydrocarbons when they hit surfaces exposed to sunlight.

SPACE ENVIRONMENTS

IONIZING RADIATION

N91-24980

THE IONIZING RADIATION ENVIRONMENT OF LDEF PRERECOVERY PREDICTIONS

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The Long Duration Exposure Facility (LDEF) was exposed to several sources of ionizing radiation while in orbit. The principal ones were trapped belt protons and electrons, galactic cosmic rays, and albedo particles (protons and neutrons) from the atmosphere. Large solar flares in 1989 may have caused a small contribution. Prior to the recovery of the spacecraft a number of calculations and estimates were made to predict the radiation exposure of the spacecraft and experiments. These were made to assess whether measurable radiation effects might exist, and to plan the analysis of the large number of radiation measurements available on the LDEF. Calculations and estimates of total dose, particle fluences, linear energy transfer spectra, and induced radioactivity were made. The principal sources of radiation will be described, and the preflight predictions summarized.

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N91-24981

GAMMA RADIATION SURVEY OF THE LDEF SPACECRAFT

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ABSTRACT

The retrieval of the Long Duration Exposure Facility (LDEF) spacecraft in January 1990 after nearly six years in orbit offered a unique opportunity to study the long term buildup of induced radioactivity in the variety of materials on board. We conducted the first complete gamma-ray survey of a large spacecraft on LDEF shortly after its return to earth. A surprising observation was the large ^{7}Be activity which was seen primarily on the leading edge of the satellite, implying that it was picked up by LDEF in orbit. This is the first known evidence for accretion of a radioactive isotope onto an orbiting spacecraft. Other isotopes observed during the survey, the strongest being ^{22}Na and ^{54}Mn, are all attributed to activation of spacecraft components in orbit. ^{7}Be is a spallation product of cosmic rays on nitrogen and oxygen in the upper atmosphere. However, the observed density is much greater than expected due to cosmic ray production in situ. This implies transport of ^{7}Be from much lower altitudes up to the LDEF orbit.

N91-24982

THE INTERACTIONS OF ATMOSPHERIC COSMOGENIC RADIONUCLIDES WITH SPACECRAFT SURFACES

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ABSTRACT

The discovery of the cosmogenic radionuclide Be-7 on the front surface (and the front surface only) of the LDEF spacecraft (Fishman et al 1991) has opened new opportunities to investigate several unexplored regions of space science. Our experiments have shown that the Be-7 found was concentrated in a thin surface layer of spacecraft material. The only reasonable source of the isotope is the atmosphere through which the spacecraft passed. We should expect that the uptake of beryllium in such circumstances will depend on the chemical form of the Be and the chemical nature of the substrate. We have found that the observed concentration of Be-7 does, in fact, differ between metal surfaces and organic surfaces such as PTFE (Teflon). We note however that (a) organic surfaces, even PTFE, are etched by the atomic oxygen found under these orbital conditions, and (b) the relative velocity of the species is 8 $km^{-1}s$ relative to the surface and the interaction chemistry and physics may differ from the norm.

Be-7 is formed by disintegration of O and N nuclei under cosmic ray proton bombardment. The principal source region is at altitudes of 12-15 km. While small quantities are produced at 300km, the amount measured on LDEF was 3 to 4 orders of magnitude higher than expected. The most reasonable explanation for this unexpected result is that Be-7 is rapidly transported from low altitudes by some unknown mechanism. The process must take place on a time scale similar to the half-life of the isotope (53 days).

Many other isotopes are produced by cosmic ray reactions, and some of these are suited to measurement by the extremely sensitive methods of accelerator mass spectrometry. We have begun a program to search for these and hope that such studies will provide new methods for studying vertical mixing in the upper atmosphere.

G.J. Fishman, et al., Nature 349, 678-680 Feb 1991.

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N91-24983

SURFACE ACTIVATION OF CONCORDE BY ^{7}Be

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ABSTRACT

Activation analysis of two airframe components from Concorde aircraft has identified the presence of ^{7}Be, a nuclide which was found by other investigators to have been collected on the forward edge of the LDEF structure. The results of the Concorde analysis indicate that this phenomenon is very much a surface effect, and that the areal densities of the ^{7}Be are comparable to those found for LDEF. The collection of ^{7}Be by the aircraft must be greater than in the case of LDEF (since the duration for which Concorde is accumulating the nuclide is shorter) and is of the order of 1.9 to 41 nuclei-cm^{-2}s^{-1}, depending upon assumptions made regarding the efficiency of the process which removes the radionuclide.

N91-24984

RADIOACTIVITIES OF LONG DURATION EXPOSURE FACILITY (LDEF) MATERIALS: BAGGAGE AND BONANZAS

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ABSTRACT

Radioactivities in materials onboard the returned Long Duration Exposure Facility (LDEF) satellite have been studied by a variety of techniques. Among the most powerful is low-background Ge-semiconductor detector gamma-ray spectrometry, illustrated here by poster presentation of results obtained at the Lawrence Berkeley Laboratory's (LBL) Low Background Facilities, in a multi-laboratory collaboration coordinated by Dr. Thomas Parnell's team at the Marshall Spacecraft Center, Huntsville, Alabama.

The observed radioactivities are of two origins: those radionuclides produced by nuclear reactions with the radiation field in orbit; and, radionuclides present initially as "contaminants" in materials used for construction of the spacecraft and experimental assemblies. In the first category are experiment-related monitor foils and tomato seeds, and such spacecraft materials as aluminum, lead, stainless steel, and titanium. In the second category are aluminum, beryllium, titanium, vanadium, and some special glasses.

Consider that measured peak-area count rates from both categories range from a "high" value of about 1 count per minute down to less than 0.001 count per minute. Successful measurement of count rates toward the low end of this range can be achieved only through low-background techniques, such as are employed at LBL to obtain the results presented here.

S13-72
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N91-24985

INDUCED RADIOACTIVITY IN LDEF COMPONENTS

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ABSTRACT

The systematics of induced radioactivity on the LDEF have been investigated in a wide range of materials using low-level background facilities for detection of gamma rays. Approximately 400 samples of materials processed from structural components of the spacecraft, as well as materials from on-board experiments, were analyzed at eight national facilities. These measurements have demonstrated the variety of radioisotopes that are produced with half-lives greater than two weeks, most of which are characteristic of proton-induced reactions above 20 MeV. For the higher-activity, long-lived isotopes, it was possible to map the depth and directional dependences of the activity.

Due to the stabilized configuration of the LDEF, the induced radioactivity data clearly show contributions from the anisotropic trapped proton flux in the South Atlantic Anomaly. This effect will be discussed, along with evidence for activation by galactic protons and thermal neutrons. Preliminary calculations using a one-dimensional model for the trapped proton flux show good agreement with the measured activations.

During this study, the discovery of beryllium-7 was made on leading side components of the spacecraft, although this was thought not to be related to the *in situ* production of radioisotopes from external particle fluxes [1] (See also J. C. Gregory, *et al.*, abstract, this conference).

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[1] G. J. Fishman, *et al.*, **Nature 349**, 678-680, Feb. 1991.

N91-24986

MEASUREMENTS OF INDUCED RADIOACTIVITY IN SOME LDEF SAMPLES

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ABSTRACT

Twenty-six stainless steel trunnion samples, five aluminum end support retainer plate samples, two aluminum keel plate samples, and two titanium clips were analyzed. The shielded high-purity germanium detectors used had efficiencies of 33%, 54%, and 80% at 1332 keV. Detector efficiencies as a function of energy and corrections for self-absorption in the samples were determined with calibrated sources, unactivated control samples, and calculations. Several measurements were made on most samples. In the trunnion samples, ^{54}Mn and ^{57}Co were seen and limits were obtained for other isotopes. The results agree well with 1-dimensional activation calculations for an anisotropic trapped proton model.[1] In the aluminum samples, ^{22}Na and ^{7}Be were seen. Other results are presented.

1) T. W. Armstrong, private communication

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N91-24987

CHARGED PARTICLE ACTIVATION STUDIES ON THE SURFACE OF LDEF SPACECRAFT

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ABSTRACT

High energy proton induced nuclear reaction products are examined using seven elements, namely; Aluminum, Silicon, Nickel, Copper, Zirconium, Tantalum and Tungsten. We detected activities due to Na-22 from Al, Co-56 and Co-57 from Ni, Co-58 from Cu and Y-88 from Zr targets. No induced activity was observed in Si, Ta and W most probably due to the long cooling times. Only Zr sample contained a weak Be-7 peak, although Ta and W were also located at the leading edge of the spacecraft. Gamma-rays of individual isotopes were measured using high-resolution Ge(Li) solid state detector coupled to 4096-multichannel analyzer. Activities were calculated for Co-56 (846 keV) and Co-57 (122 and 136 keV's) at the time of the entry of the spacecraft and found to be 0.014±0.005 c/sec. g, 0.018±0.002 c/sec. g, and 0.0024±0.0007 c/sec. g, respectively.

S16-72

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GAMMA-RAY SPECTROMETRY OF LDEF SAMPLES AT SRS

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ABSTRACT

A total of 31 samples from LDEF, including materials of aluminum, vanadium, and steel trunnions were analyzed by ultra-low-level gamma spectrometry. The study quantified particle induced activations of ^{22}Na, ^{46}Sc, ^{51}Cr, ^{54}Mn, ^{56}Co, ^{57}Co, ^{58}Co, and ^{60}Co. The samples of trunnion sections exhibited increasing activity toward the outer end of the trunnion and decreasing activity toward its radial center. The trunnion sections did not include an end piece that collects noticeable ^{7}Be on its leading surface[1]. No significant ^{7}Be was detected in the samples analyzed.

The Underground Counting Facility at Savannah River Laboratory was used in this work[2]. The facility is 50 ft underground, constructed with low-background shielding materials, and operated as a clean room. The most sensitive analyses were performed with a 90%-efficient HPGe gamma-ray detector, which is enclosed in a purged active/passive active shield. Each sample was counted for 1-6 days in two orientations to yield more representative average activities for the sample. The non-standard geometries of the LDEF samples prompted the development of a novel calibaration method, whereby the efficiency about the sample surfaces (measured with point sources) predicted the efficiency for the bulk sample.

The information contained in this article was developed during the course of work under Contract No. DE-AC09-89SR18035 with the U.S. Department of Energy.

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2. W.G. Winn, W.W. Bowman, A.L. Boni, "Ultra-Clean Underground Counting Facility for Low-Level Environmental Samples", The Science of the Total Environment, 69, 107 (1988).

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P.1

N91-24989

CHARGED PARTICLE LET-SPECTRA MEASUREMENTS ABOARD LDEF

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ABSTRACT

The linear energy transfer (LET) spectra of charged particles has been measured in the 5-250 keV/μm (water) interval with CR-39 and in the 250-1000 keV/μm (water) interval with polycarbonate plastic nuclear track detectors (PNTDs) under different shielding depths in the P0006 experiment. The optimal processing conditions were determined for both PNTDs in relation to the relatively high track densities due to the long-term exposure in space. The total track density was measured over the selected samples, and tracks in coincidence on the facing surfaces of two detector sheets were selected for measuring at the same position on each sheet. The Short Range (SR) and Galactic Cosmic Ray (GCR) components were measured separately. The integral dose and dose rate spectra of charged particles are also given. The high LET portion of the LET spectra was measured with high statistical accuracy. This is a unique result of this experiment due to the low flux of this type of particle under typical shielding conditions. The directional dependence of the charged particles at the position of the P0006 experiment was also studied by four small side stacks which surrounded the main stack and by analyzing the dip angle and polar angle distributions of the measured SR and GCR particle tracks in the main stack.

Experiment No. P0006

N91-24990

THERMOLUMINESCENT DOSIMETER MEASUREMENTS AND ANALYSIS FOR LDEF EXPERIMENT M0006

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ABSTRACT

The paper will report on glow curve measurements up to 600°C of TLD-100 (LiF) samples deployed on LDEF and retained as ground control. It will also report on laboratory exposure simulations with Co-60 radiation, low-energy light ions and high energy protons in an effort to replicate the glow curves, especially the high temperature peaks observed in the LDEF TLD specimens. Our evidence to date clearly shows the effect of in-flight anneal on the low temperature part of the glow curve. It also shows that the high temperature part of the glow curve appears due to ion dose deposition. Initial correlations between high-temperature glow peaks and effective LET of the registered dose will be given.

Experiment No. M0006

N91-24991

RADIATION CALCULATIONS AND COMPARISONS WITH DATA*

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ABSTRACT

In conjunction with the analysis of data from LDEF ionizing radiation dosimetry, a calculational program has been established to aid in data interpretation and to assess the accuracy of current radiation environments and effects models for future mission applications. Initial estimates of LDEF exposure to trapped, galactic, and atmospheric (albedo) radiation sources have been made, and the radiation environment (primary and secondary particle spectra) and several radiation effects (induced radioactivity and dose) for varying amounts of LDEF shielding have been calculated for a simplified LDEF mass model. Preliminary comparisons of the calculated results have been made with the induced radioactivity measurements for several LDEF components and with preliminary dose data from several experiments (P0004, P0006, and M0004). Predictions have been compared with the radioactivity induced in the aluminum clamps holding the experiment trays and in the stainless steel trunions to test a recently developed theory of trapped proton anisotropy.

*Research sponsored by NASA Marshall Space Flight Center

N91-24992

LDEF GEOMETRY/MASS MODEL FOR RADIATION ANALYSES*

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ABSTRACT

A three-dimensional geometry/mass model of LDEF has been generated to (1) aid in the interpretaion of ionizing radiation experiments relative to the influence of varying shielding distributions around the dosimetry, and (2) to allow more definitive calculations and comparisons with the measured data. This model takes into account the major individual structural members of the LDEF spacecraft, the mass in each experiment tray, and, for selected trays containing ionizing radiation dosimetry, major components within the tray are modeled. The geometry/mass model, together with ray-tracing algorithms, has been programmed for use both as a stand-alone code in determining 3-D shielding distributions at dosimetry locations, and as a geometry module that can be interfaced with radiation transport codes.

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*Research sponsored by NASA Marshall Space Flight Center

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N91-24993

RADIATION EXPOSURE OF LDEF: INITIAL RESULTS

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ABSTRACT

Initial results from LDEF include radiation detector measurements from four experiments, P0006, P0004, M0004 and A0015. The detectors were located on both the leading and trailing edges of the orbiter and also at the Earthside end. This allowed the directional dependence of the incoming radiation to be measured. Total absorbed doses from thermoluminescent detectors (TLDs) verified the predicted spatial east-west dose dependence of a factor of ~2.5, due to trapped proton anisotropy in the South Atlantic Anomaly (SAA). On the trailing edge of the orbiter a range of doses from 664 to 291 rad were measured under nominal shielding of 0.42 to 8.45 g/cm^2. A second set of detectors near this location yielded doses of 648 to 266 rad under nominal shielding of 0.47 to 12.9 g/cm^2. On the leading edge doses of 258 to 210 rad were found under shielding of 1.25 to 2.48 g/cm^2. Initial charged particle LET (linear energy transfer) spectra, fluxes, doses and dose equivalents, for LET in H_2O ≥5 keV/μm, have been measured with plastic nuclear track detectors (PNTDs) located in the four experiments. Also, preliminary data on low energy neutrons were obtained from detectors containing ^{6}LiF foils. The radiation data contained in the LDEF mission represent an invaluable asset and one which is not likely to be duplicated in the foreseeable future. The data and the subsequent knowledge which will evolve from the analysis of the LDEF experiments will have a very important impact on the design and construction of the Space Station Freedom and on other long-term space missions.

Experiment No. P0006

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N91-24994

THE LDEF ULTRA HEAVY COSMIC RAY EXPERIMENT

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ABSTRACT

The LDEF Ultra Heavy Cosmic Ray Experiment (UHCRE) employed sixteen side viewing LDEF trays giving a total geometry factor for high energy cosmic rays of 30 m^2sr. The total exposure factor was 170 m^2sr y. The experiment is based on a modular array of 192 solid state nuclear track detector stacks, mounted in sets of four in 48 pressure vessels (three per experiment tray). The extended duration of the LDEF mission has resulted in a greatly enhanced potential scientific yield from the UHCRE. Initial scanning results indicate that at least 2000 cosmic ray nuclei with $Z > 65$ have been collected, including the world's first statistically significant sample of actinides. Post-flight work to date and the current status of the experiment are reviewed. Provisional results from analysis of pre-flight and post-flight calibrations are presented.

Experiment No. A0178

S23-72
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P.1

N91-24995

PRELIMINARY RESULTS FROM THE HEAVY IONS IN SPACE EXPERIMENT

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ABSTRACT

The Heavy Ions in Space (HIIS) experiment is intended to provide a deep survey of intensely ionizing particles in low earth orbit. Intensely ionizing particles produce single event effects in microelectronic components and are now recognized as the principal cause of spacecraft anomalies. These particles also make an important contribution to radiation doses.

Besides the practical applications, HIIS data will be used to investigate several important scientific questions. By measuring heavy ions that stop in HIIS, we can investigate the anomalous component of cosmic rays, search for evidence of heavy ions trapped in the earth's magnetic field and by comparing HIIS data with observations from outside the magnetosphere we can determine the mean ionic charge state of solar energetic particles. HIIS will also record relativistic ultraheavy galactic cosmic rays. We will be able to measure their elemental composition from tin to uranium.

Results will be presented on the elemental resolution for stopping heavy ions and and relativistic heavy ions. We will also discuss the possible origin of the stopping heavy ions observed to date in HIIS.

Experiment No. M0001

S04-72
N91-24996
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p.1

HEAVY ION MEASUREMENT ON LDEF

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ABSTRACT

The Kiel LDEF experiment M0002, mounted on experiment tray E6, was designed to measure the heavy ion environment by means of CR-39 plastic solid state track detectors. The detector stack with a size of 40*34*4.5 cm^3 was exposed in vacuum covered by thermal protection foils with a total thickness of approximately 14 mg/cm^2. After etching small samples of the detector foils tracks with $Z \geq 6$ could be easily detected on a background of small etch pits, which were probably produced by secondaries from proton interactions.

The LDEF orientation with respect to the magnetic field lines within the South Atlantic Anomaly (SAA) is expected to be constant during the mission. Therefore we measured the azimuth angle distribution on the detector foils for low energy stopping particles. All detected arrival directions are close to a plane perpendicular to the magnetic field line of -20° declination and -40° inclination at location 34° W and 27° S (included in this preliminary analysis are foils exposed in experiment A0015).

Together with the steep energy spectrum this spatial distribution close to the mirror plane in the SAA is an evidence that we detected heavy ions from a radiation belt population.

S25-72
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N91-24997

SUMMARY OF IONIZING RADIATION ANALYSIS ON THE LONG DURATION EXPOSURE FACILITY

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ABSTRACT

The Ionizing Radiation Special Investigation Group (IRSIG) for the Long Duration Exposure Facility (LDEF) was established to perform radiation measurements and analysis not planned in the original experiments, and to assure availability of LDEF analysis results in a form useful to future missions. The IRSIG has organized extensive induced radioactivity measurements throughout LDEF, and a comprehensive program to compare the LDEF radiation measurements to values calculated using environment models. The activities and present status of the Group will be described. The presentation will also summarize the ionizing radiation results presented at this conference.

SPACE ENVIRONMENTS

METEOROID

AND DEBRIS

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N91-24998

LARGE CRATERS ON THE METEOROID AND SPACE DEBRIS IMPACT EXPERIMENT

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ABSTRACT

The distribution around the LDEF of 532 large craters in the aluminum plates from the Meteoroid and Space Debris Impact Experiment (S0001) will be discussed along with 74 additional large craters in aluminum plates donated to the Meteoroid and Debris Special Investigation Group by other LDEF experimenters. The craters are 0.5 mm in diameter and larger. Crater shape will be discussed. The number of craters and their distribution around the spacecraft will be compared with values predicted with models of the meteoroid environment and the manmade orbital debris environment.

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N91-24999

STUDY OF METEOROID IMPACT CRATERS ON VARIOUS MATERIALS
(A0 138-1)

ATTEMPT AT DUST DEBRIS COLLECTION WITH STACKED DETECTORS
(A0 138-2)

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ABSTRACT

Part of the LDEF tray allocated to French experiments, known as FRECOPA payload, has been devoted to the study of dust particles. The tray was located on the face of LDEF directly opposed to the velocity vector (west facing direction, location B3).

Two passive experiments have been flown : one composed of a set of glass and metallic samples and one composed of multilayer thin foils detectors.

Collection area was about 2000 cm2. In addition of these dedicated experiments a broad variety of materials has been exposed to the bombardment of microparticles and provide additional data.

Thick target experiment comprises selected metallic (Al, Au, Cu, W, Stailess Steel, thickness = 250 µm) and glass surfaces 1.5 mm thick.

Crater size distribution from these thick target experiments will enable, with the aid of laboratory calibration by solid particle accelerators, the evaluation of the incident microparticle flux in the near earth environment.

The aim of the multiple foil penetration and collection experiment is primarly to investigate the feasability of multilayer thin film detectors acting as energy sorters in order to collect micrometeoroids, if not in their original shape, at least as "break-up" fragments suitable for chemical analysis. Foil thickness ranges from 0.75 µm to 5 µm of aluminium.

Many large impact features have been found on FRECOPA : especially one full penetration and one marginal penetration of a 1 mm aluminium shield. About 90 craters larger than 50 µm have been found on a total area of one square meter. Most of the large craters are circular in outline, with a depth to diameter ratio of about 0.55, however some small craters do indicate oblique incidence.

The crater size distribution should be converted to a particle mass distribution by using relevant relationship between crater sizes and particles mass and velocity. Assuming an average impact velocity of 15 km/s, the value of the crater diameter to the particle diameter ratio, could be chosen as D/d = 5, for aluminium targets.

The size distribution in comparison with review of comparable near-earth data shows a good agreement, flux on the west face of LDEF is about 20 times lower than on the east face, for large particles. Most of the particles impacting this face should be interplanetary dust particles, not orbital debris. This fact will be substantiated further by the chemical identification of projectile remnants inside craters.

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N91-25000

METEOROID/SPACE DEBRIS IMPACTS ON MSFC LDEF EXPERIMENTS

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ABSTRACT

This paper presents the numerous meteoroid and space debris impacts found on A0171, A0034, S0069, and other MSFC experiments. Besides those impacts found by the meteoroid and debris special investigative group at KSC, numerous impacts <0.5 mm have been found and photographed. The flux and size distribution of impacts will be presented as well as EDS analysis of impact residue. Emphasis will be on morphology of impacts in the various materials, including graphite/epoxy composites, polymeric materials, optical coatings, thin films, and solar cells.

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N91-25001

METEOROID/SPACE DEBRIS IMPACTS ON MSFC LDEF EXPERIMENTS

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ABSTRACT

This paper presents a number of unusual effects that were observed on the TCSE test samples, front cover, and structural components. These include induced ultraviolet (UV) fluorescence in some materials, the migration and degradation of KRS-5 materials, atomic oxygen (AO) and contaminant texturing/discoloration, and meteoroid and debris impacts. These effects and their causes will be discussed.

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N91-25002

FOIL PERFORATION PARTICULATE IMPACT RECORDS ON LDEF MAP AO023: INCIDENT MASS DISTRIBUTIONS

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ABSTRACT

An array of multiple foils varying from 1.5μm to 30 μm exposed on LDEF's geocentrically stabilised exposure platform provides perforation distributions which relate to particulate flux mass distributions and impact velocity in LDEF's orbital reference frame. The application of physical modelling (1) enables a preliminary separation into orbital and interplanetary components, both of which have differing velocities and hence penetration effectiveness.

Thin foil hypervelocity calibration data (2,3) and parametric penetration formulae developed to relate target hole diameter to projectile dimension (4,5) are critically examined and a new formula offered for the ballistic limit situation. Incorporating projectile density, target density and target strength and dimensional scaling from submicron particulates to centimetre scale data (6), it contrasts very significantly with previous formulae (5) in the interpretation of space impact data.

Perforation flux distributions for the leading, trailing and space pointing faces and associated mass distributions for the two populations are presented.

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p. 1

METEOROID AND ORBITAL DEBRIS RECORD OF THE LONG DURATION EXPOSURE FACILITY

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INTRODUCTION: The Long Duration Exposure Facility (LDEF) was recovered in January, 1990 following 5.7 years exposure of ~130 m^2 of surface area in low-Earth orbit (250-179 miles). Since LDEF was gravity stabilized, each of LDEF's 26 different facing directions were constant with respect to the spacecraft's velocity vector. Thus, studies of LDEF's impact record will contribute to the resolution of the meteoroid and space-debris flux. Because LDEF offered such an opportunity, the Meteoroid and Debris Special Investigation Group (M&D SIG) was organized to achieve this end [1]. During deintegration of LDEF at the Kennedy Space Center (KSC) in the spring of 1990, M&D SIG members harvested detailed data on all large impacts (~500), as well as surveyed the spacecraft for all visible, smaller impacts (~30,000). For information on the techniques and procedures used during the KSC-data acquisition, interested readers should see [1]. The KSC-acquired data are presently being reduced to yield accurate impact-crater depths and diameters. Here we present a preliminary accounting of the impact record based on ~15.4 m^2 surface area of LDEF's 6061-T6 aluminum frame, which was exposed in all 26 different direction.

RESULTS AND DISCUSSION: The amount of LDEF-frame surface area exposed in the 26 different directions varied from 0.53 to 0.79 m^2. A total of 433 impacts $\geq$0.5 mm in diameter were photodocumented; the areal density of impacts varied from 0 to 78.5 impacts/m^2 on the Space-end and Row 9.5, respectively. It is clear that the population and space-exposed area are statistically large enough to yield information on the flux of particles in low-Earth orbit. There should be a forward-facing (Row 9) enhancement of the impact frequency relative to the rear-facing (Row 3) direction [2]. The observed ratio of leading-edge to trailing-edge impacts for the $\geq$0.5 mm diameter features is 10, compatible with some previous estimates [2], but Row 9 does not contain the maximum crater density.

The expected regular increase in impact frequency from Row 3 to Row 9 was not observed in the preliminary frame data that is illustrated in Figure1a. Impact-frequency maxima are seen on either side of Row 9, but Row 9 itself shows a dramatic decrease. Although a minor decrease might be expected in the leading-edge direction, the observed value far exceeds what might have been expected (Zook and Kessler, pers. comm., 1990). Figure 1b shows the effects of fitting a Gaussian curve, through the method of least squares, to the impact frequency data of the LDEF frame. From this figure a ratio of approximately 20:1 is obtained for the impact frequency of LDEF's leading edge to trailing edge. If these results are correct, they suggest that some principal components of the particle complex in low-Earth orbit have non-random trajectories. On the basis of the observed crater diameters, these would be particles >0.1 mm in diameter. Modeling suggests that micrometeoroids are dominant in this size range [2].

To foster continued studies, the M&D SIG has carefully selected a large variety of materials containing impact features from LDEF and returned them to the Curatorial Facility at the Johnson Space Center. All of these surfaces are available for allocation to qualified investigators.

REFERENCES: [1] See *et al.* (1990) *Micrometeroid and Debris Impact Features Documented on the Long Duration Exposure Facility, A Preliminary Report*, Planet. Sci. Branch Pub. 84; [2] Zook (1990), *LPSC XXI*, 1385-1386.

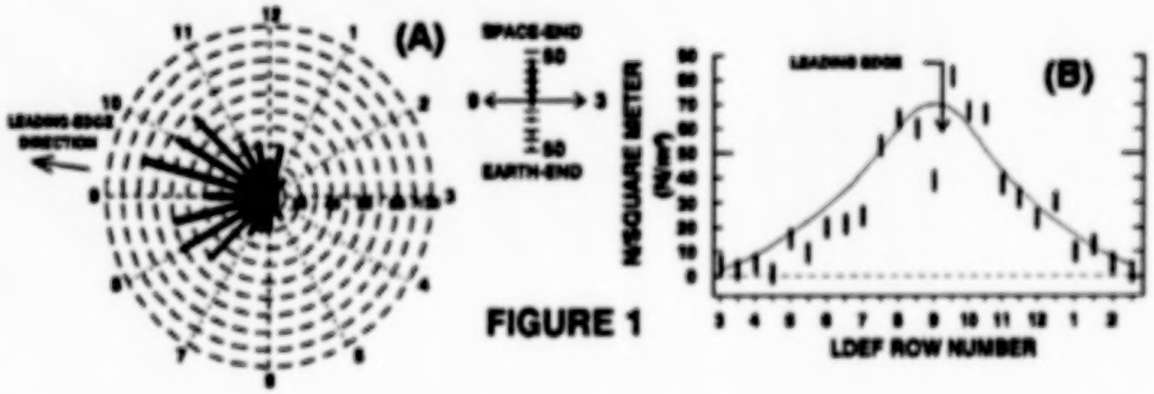

FIGURE 1

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N91-25004

PARTICULATE IMPACTS ON THE UHCRE COSMIC RAY EXPERIMENT TEFLON COVERS: THE ESA PROGRAMME

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ABSTRACT

The optical scanning equipment at the University of Kent, Unit for Space Science consists of a 102.5 x 42.5 cm computer controlled motorised stage which has a reproduction accuracy of 30 microns over the entire area. This is used with an optical microscope connected to two CCD video cameras which can be used to obtain stereo, colour images of any features found. The system can take images with field sizes of 12.6, 8.14, 4.93, 2.98 and 1.94 mm which are digitised in a 512 by 512 array giving a maximum resolution of 4 microns.

A coordinate system can be defined on each cover by means of two or more reference marks which allow a feature to be located using different equipment such as an SEM providing two known marks can be found. By using back illumination penetrating features can be found automatically and their sizes, circularity and positions logged for later revisiting either on the optical system or using an SEM.

The images of each feature are stored as 720 by 512 bitmaps with 256 levels in each of the red, green and blue components and are stored on DC600A cartridges as SUN rasterfiles. The actual resolution of the images is always somewhat less than this though and depends of the focus chosen, images taken through the FEP teflon top layer are degraded somewhat especially if the FEP is discoloured. All images have a line of text giving the feature a unique identifier such as A10C0006ac which means this image is of cover A10, section C, feature number 6, image number 2 (the aa=0, ab=1, ac=2, ...) plus the coordinates and a scale. A library of such images is being assembled complete with data on the craters entry size, exit size, ellipticity, orientation of the ellipse, radial cracks and halo.

Summary performance data and impact particulate distributions will be presented and intercompared with the wider body of LDEF experimental data.

S33-93

N91-25005

PRELIMINARY RESULTS FROM THE CHEMISTRY OF MICROMETEOROID EXPERIMENT (AO 187-1)

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The purpose of experiment A-187-1 was to expose high purity substrates of suitable cratering properties to obtain detailed crater statistics that may be converted into projectile masses and fluxes and to chemically characterize as many impactors as possible, preferably all. The latter information will hopefully reveal distinct classes of natural and man-made particles in LEO.

Operationally, we have completed all optical surveying of impact features on LDEF trays A11 (aluminum collectors) and A3 (gold-collectors); we have also dislodged all major craters from the Au-surfaces (N= appr. 240) and form 1/3 of the Al-collectors (N= 260). Survey type SEM studies (crater morphology and preliminary chemical composition) are complete on some 350 craters.

The crater statistics accounted for all craters > 50 um; features > 20 um were counted on some select, yet representative, surfaces which were scanned at high magnification. We also scanned the actual tray-lips (6061 T6 aluminum). The crater diameters were converted into projectile diameters (Dp) using experimentally determined crater-scaling laws. The projectile number densities at Dp =10 um differ between the forward facing A11 surfaces and the trailing edge (A3) gold collectors by approximately factor of 5. The A3 tray-lips experienced a factor of 1.8 more impacts than did the gold-surfaces, suggesting that the clam-shell type device opened and closed nominally throughout the entire LDEF mission.

We find that analysis of projectile residues is generally very difficult. All surfaces, other than the 99.99% pure Au-substrates, seem plagued by non-homogeneous distribution of contaminants, both intrinsic to the 1100 or 6061-series aluminum alloys, as well as surface deposits (e.g. Ca+Si-rich deposits, presumably degassed RTV; or abundant Na and NaCl, most likely aquired during ground-processing at KSC). Many of the craters yield no traces of projectile residue at the sensitivity levels of the SEM-EDAX systems used at JSC and Wash. Univ., most likely due to complete vaporization at high encounter velocities. Nevertheless, those craters that yield residues show that natural and man-made impactors may be differentiated and that diversity exists within each group. "Chondritic" compositions dominate among natural particles, yet some craters contain unmelted fragments of minerals (olivine and pyroxene). We also ascribe residues containing Ca, Si, Mg and Fe in apparently non-chondritic proportions to "natural" sources. Among man-made debris we recognized paint-flakes, silver-solder, and Ti, Ni and Cr rich compounds (stainless steel?). It is expected that this survey type assessment is completed by late May and that relative frequencies of diverse particle types can be presented at the LDEF Symposium.

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N91-25006

SIMS ANALYSIS OF EXTENDED IMPACT FEATURES ON LDEF EXPERIMENT AO189-2

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ABSTRACT

Reported are the first SIMS analysis of projectile material deposited in extended impact features on Ge wafers from the trailing edge. Although most capture cells lost their plastic film covers, they contain extended impact features that apparently were produced by high velocity impacts when the plastic foils were still intact. Detailed optical scanning of all bare capture cells from the trailing edge revealed more than 100 impacts, 58 were selected by SEM inspection as prime candidates for SIMS analysis. Preliminary SIMS measurements were made on 15 impacts. More than half showed substantial enhancements of Mg, Al, Si, Ca and Fe in the impact region, indicating micrometeorites as the projectiles. Preliminary isotopic analysis of two impacts will also be reported.

N91-25007

ION MICROPROBE ELEMENTAL ANALYSES OF IMPACT FEATURES ON INTERPLANETARY DUST EXPERIMENT SENSOR SURFACES.

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ABSTRACT

Hypervelocity impact features on several of the electro-active dust sensors utilized in the IDE experiment were subjected to elemental analyses using an ion microprobe. The negatively biased dust sensor surfaces acted as ion traps for cations produced in the plasma plumes of impacting particles. Impactor residue surrounds most impact features out to two or three feature diameters. After etching away a layer of carbonaceous/silicaceous surface contamination, low mass resolution elemental survey scans are used to tentatively identify the presence of impactor debris. High mass resolution two-dimensional elemental maps and three-dimensional depth profiling of the feature and surrounding area show the distribution and relative composition of the debris. The location of these sensors on the six primary LDEF sides (rows 3, 6, 9, 12, space end, and earth end) provides a unique opportunity to further define the debris environment. We have applied the same techniques to impact and contaminant features on a set of ultra-pure, highly polished single-crystal germanium wafer witness plates that were mounted on row 12 and exposed to the environment during the entire mission.

Experiment No. A0201

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N91-25008

LDEF IMPACT CRATERS FORMED BY CARBON-RICH IMPACTORS

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ABSTRACT

Two small craters (#74, 119 μm and #31, 158 μm in dia.) with depth to diameter ratios of ≈ 0.59 and 0.8, respectively, were found in Al from LDEF experiment tray A11E00F (F. Horz, P. I.). Both craters have residues concentrated in the crater bottoms, along the walls, and on the top of the overturned rims. Low voltage scanning electron microscopy (LVSEM), Auger electron spectroscopy (AES), time-of-flight secondary ion mass spectroscopy (TOF-SIMS) and SEM-EDS have been used to obtain high resolution imagery and elemental analyses.

AES analyses indicate that the impactor for both craters was carbon-rich as the residues contain mostly C (and Al from the panel; oxygen is present in stoichiometric proportions with Al to form Al_2O_3). Silicon, S, and F are present in low concentrations on the Al surface away from the craters and may be, in part, contaminates. Crater 74 contains intrinsic Mg at the few % level. SEM-EDS analyses show the presence of Mg, Si, S, Ca, Fe and Ni in the residue in the bottom of crater 31 which implies a chondritic composition. Auger carbon surveys from the bottom of crater 31, 25 μm away from the crater, and 1 mm away from the crater show C surface concentrations of ≈ 40, 9, and 4 atomic %, respectively. Similar concentrations were found for crater 74, which also has round to irregular lumps in the crater bottom of C surface contents of between 72 and 54 atomic %.

TOF-SIMS analyses indicate low levels of Na, K, Ag, and I on the top of the raised rim of crater 31 (in addition to Fe and Ca), which may be contaminates. Moreover, TOF-SIMS spectra indicate the presence of organic fragment ions, including aromatic species such as $C_5H_5^+$, $C_7H_7^+$ and $C_8H_5O_3^+$, generally associated with the raised rim and likely to be contaminates as well. A small spot exhibiting elevated levels of Cl was observed on the wall of crater 31.

The existence of impactor residue in the two craters implies impact velocities of < 6 km based on experimental hypervelocity impact studies. On-going isotopic ratio imaging analyses are being conducted to find extraterrestrial isotopic signatures for the carbonaceous material (C and H).

M & D SIG investigation Report

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IDE SPATIO-TEMPORAL IMPACT FLUXES AND HIGH TIME-RESOLUTION STUDIES OF MULTI-IMPACT EVENTS AND LONG-LIVED DEBRIS CLOUDS

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P. 1

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ABSTRACT

During the first 12 months of the LDEF mission, the Interplanetary Dust Experiment (IDE) recorded over 15000 total impacts on six orthogonal faces with a time resolution on the order of 15-20 seconds of time. When combined with orbital data and the stabilized configuration of the spacecraft, this permits a detailed analysis of the micro-particulate environment. The functional status of each of the 459 detectors was monitored every 2.4 hours, and post-flight analysis of these data has now permitted an evaluation of the effective active detection area as a function of time, panel by panel and separately for the two sensitivity levels. Thus, impact totals have been transformed into areal fluxes, and are presented here for the first time. Also discussed here are possible effects of these fluxes on previously-announced results: apparent debris events, meteor stream detections, beta meteoroids in observationally significant numbers.

Systematic examination of the impact history reveals numerous concentrated bursts that are not randomly distributed in time, but often found in sequences. Fourier frequency analysis showed strength in the LDEF orbital period (94 min), indicating clouds of particulates through which the spacecraft passed on successive orbits. The largest multi-hit event recorded 131 impacts within a 3-minute interval on 4 June 1984; this is nearly 1% of all the hits during the entire active mission! It was also the first of a series of events at essentially the same orbital longitude on numerous near-consecutive LDEF orbits, at least 25 encounters over a 2-day space. During this time, the LDEF orbit precessed through nearly 25 degrees. This is clearly a massive orbital debris cloud. Small but significant non-random events are detectable 53 days later; if one assumes that the two sequences are related, then one can estimate the precession period and orbit inclination of the debris cloud. This gives a strong clue to its source. Six such events during the mission produce about 25% of all the impacts recorded.

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Experiment No. A0201

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N91-25010

DYNAMIC (COMPUTER) MODELLING OF THE PARTICULATE ENVIRONMENT: TRANSFORMATIONS FROM THE LDEF REFERENCE FRAME TO DECODE GEOCENTRIC ANDINTERPLANETARY POPULATIONS

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ABSTRACT

LDEF's impact signature record and, in particular the size frequency distribution of craters and perforations (1) offers a unique record of environmental data referenced conveniently to the geocentric reference frame.

Its exposure simultaneously to both orbital and to geocentrically unbound interplanetary particulates does, however, present probelms in decoding the two populations. Chemical analysis of residues can offer only limited assistance and hence flux modelling has been developed (2,3) to transform from both geocentric orbital (e = 0) distributions and geocentrically unbound interplanetary source distributions. This is applied to the foil and crater penetration records (1,4) in the Ram (E), Trailing (W) and Space pointing directions to offer the means of decoding the records. It shows that the mix of the components is size dependent; though the interplanetary component dominates at greater than some 5 microns particulate diameter an increasing orbital component is evident. Arguments for the space age origin of the micro particulates are not convincing dynamically and it is questionable whether the Solar Maximum Mission data (5) has been correct in the attribution of the population exclusively to space micro-debris.

Parametric forms of the modelling transformations are presented for the orbital and unbound populations.

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N91-25011

LDEF DATA CORRELATION TO EXISTING NASA DEBRIS ENVIRONMENT MODELS

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ABSTRACT

The Long Duration Exposure Facility (LDEF) was recovered in January, 1990, following 5.75 years exposure of ~130 m^2 to low-Earth orbit. Approximately 25 m^2 of this surface area was aluminum 6061 T-6 exposed in every direction. In addition, approximately 17 m^2 of Scheldahl G411500 silver-Teflon thermal control blankets were exposed in nine of the twelve directions. These two types of surfaces provide a unique source of statistical data on impact directionality and flux into two well characterized materials.

Since LDEF was gravity-gradient stabilized and did not rotate, the directional dependence of the flux can be easily distinguished. During the deintegration of LDEF, all impact features larger than 0.5 mm into aluminum were documented for diameters and locations. In addition, the diameters and locations of all impact features larger than 0.3 mm into Scheldahl G411500 thermal control blankets were also documented. This data, along with additional information collected from LDEF materials archived at NASA Johnson Space Center (JSC) on smaller features, will be compared with current meteoroid and debris models. This comparison will provide a validation of the models and will identify discrepancies between the models and the data.

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N91-25012

DERIVING THE VELOCITY DISTRIBUTION OF METEOROIDS FROM THE MEASURED METEOROID IMPACT DIRECTIONALITY ON THE VARIOUS LDEF SURFACES

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ABSTRACT

Because of spacecraft motion, a much higher flux of meteoroids is expected to strike the leading (apex) surface of a spacecraft than is expected to strike the trailing (antapex) surface. As earlier noted (1), the ratio of fluxes--apex to antapex--depends on the velocity distribution of meteoroids entering the Earth's atmosphere; the ratio ranges from 5.7 to 9.2 at constant meteoroid mass for the three velocity distributions examined (1). The velocity of impact is also greater, on average, on the apex surface than on the antapex surface (1), and the impacts tend to be more normal to the surface. This means that the meteoroids that make a crater of a given diameter are less massive for those that strike the apex surface than for those that strike the antapex surface. These effects further increase the apex-antapex abundance ratio at constant crater diameter compared to that at constant mass (2). For craters 100 microns in diameter on 6061 T6 aluminum on LDEF, the ratios obtained (2) on various surfaces are given in Table 1.

Table 1. Relative production rates of 100 micron diameter craters due to meteoroids impacting on various LDEF surfaces as a function of the meteoroid velocity distribution (E-K = Erickson-Kessler; S&S = Southworth & Sekanina; see (2) for references).

Vel. dist.	Apex	Top	Side	Antapex	Bottom
Dohnanyi	9.9	5.9	4.2	1	0.13
E-K	14.4	7.6	5.4	1	0.17
S&S	21.2	10.1	7.2	1	0.23

Thus we see that a determination of the meteoroid impact crater abundances on the various LDEF surfaces will make it possible to decide which meteoroid velocity distribution in Table 1 is preferable. Or, perhaps, a new distribution will be suggested. It should then be possible to estimate the relative abundance of meteoroids derived from asteroids compared to those derived from comets, as asteroidal particle velocities are, on average, much lower than are cometary particle velocities (3). Singer et al. (4) have sensed beta meteoroids on the antapex surface of LDEF. If the flux of beta's can also be measured on other surfaces, it should be possible to derive an "effective" velocity for these meteoroids; this has not yet been experimentally determined.

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P. 1

M&D SIG PROGRESS REPORT: LABORATORY SIMULATIONS OF LDEF IMPACT FEATURES

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Laboratory impact experiments are needed to understand the relationship between a measured penetration hole diameter and associated projectile dimension in the thermal blankets of experiment A0178, which occupied some 16 m2. These blankets are composed of 125 um thick teflon that has an Ag/enconel second mirror surface, backed by organic binder and Chemglaze paint for a total thickness of some 170 um. While dedicated experiments are required to understand the penetration behavior of this compound target in detail, we report here on impact simulations sponsored by other projects into pure teflon and aluminum targets. These experiments will allow first order interpretations of impact features on LDEF, and they will serve as guides for dedicated experiments that employ the real LDEF-blankets, both unexposed and exposed, for a refined understanding of LDEF's collisional environment.

We employed a light gas gun to launch soda-lime glass spheres from 50 to 3200 um in diameter (Dp) that impacted targets of variable thickness (Tf). The foil thickness is "scaled" to projectile dimensions via the ratio Dp/Tf and we systematically varied this ratio from approximately 0.2 (= infinite halfspace target giving rise to a full cratering event) to some 200 (=pure penetration without projectile fragmentation). All experiments were conducted at a nominal 6 km/s and at normal incidence. We found the crater diameter (Dc) to be some 5 times the projectile diamater in aluminum (1100 series) and some 3.8Dp in teflon. All penetrations up to Dp/Tf=1 are in essence truncated craters that are characterized by the above diameter-relationships. With successively thinner targets, the penetration holes (Dh) decrease systematically to approximate the ideal condition of Dh=Dp at some Dh/Tf > 30 in teflon and at Dp/Tf > 50 in aluminum. These systematic relationships between measured hole diameter and known blanket thickness allow unique solutions for particle diameter Dp at constant (presently 6 km/s) encounter velocity. Additional experiments are needed that explore velocity-dependent effects and how they may be scaled to applicable, cosmic velocities, which are currently beyond light gas gun launch capabilities.

The largest penetration measured in an LDEF thermal blanket is approximately 3 mm in diameter. Thus all penetrations occured at Dp/Tf < 20. As a consequence, Dh=Dp will not apply to a single event and all holes must be larger than projectile diameter. The far majority of LDEF penetrations are < 1mm and thus occured at Dp/Tf < 6; the latter condition results in typical hole diameters that are factors of 2-3 larger than the projectile. Because Dp is cubed to obtain projectile mass, such factors of 2-3 become crucial in obtaining accurate particle mass-frequencies and fluxes.

N91-25014

PRELIMINARY MICROMETEOROID AND DEBRIS EFFECTS ON LDEF THERMAL CONTROL SURFACES

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ABSTRACT

Thermal control surfaces returned from space exhibited synergistic effects of simultaneous exposure to various natural environments. These environments included meteoroid and debris impacts, thermal cycling, atomic oxygen, and ultra-violet light exposure. The combined effects of these environments were most prominent in the region surrounding meteoroid and debris impact features in thermal control surfaces. Indications of these effects were noted in several phenomena, such as the silver-oxide rings and large delamination areas surrounding penetrations through silvered-Teflon thermal control blankets, and the large spallation zones and delamination rings caused by impacts into atomic oxygen eroded thermal control paints.

The thermal controls surfaces on the Long Duration Exposure Facility (LDEF) were exposed to 5.75 years of low-Earth orbit environments. Since LDEF was gravity-gradient stabilized and directionally stable (i.e. no rotation), the effects of each of the environments can be distinguished via changes in material responses to hypervelocity impacts. The extent of these effects are being visually and microscopically characterized using thermal control surfaces archived at NASA Johnson Space Center (JSC) in order to determine the relationship between environment exposure and resulting ring sizes, delamination areas, and penetration diameters. The characterization of these affected areas will provide spacecraft system designers with the information they require to determine degradation of thermal control systems during satellite lifetimes.

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SPACE ENVIRONMENTS

ATOMIC SPECIES

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THE INTERSTELLAR GAS EXPERIMENT (IGE)

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ABSTRACT

The Interstellar Gas Experiment (IGE) exposed thin metaliic foils in order to collect neutral particles from the interstellar gas which penetrate the solar system due to their motion relative to the sun. These particles were entrapped in the foils along with precipitating magnetospheric and ambient atmospheric particles. Seven of these foils collected particles arriving from seven different directions as seen from the spacecraft for the entire duration of the LDEF mission. In our mass spectrometric analysis of the noble gas component of these interstellar particles we have so far detected the isotopes of ^{3}He, ^{4}He, ^{20}Ne, and ^{22}Ne. These preliminary measurements suggest that the various isotopes are occurring in approximately the expected amounts, and that their distribution in direction of arrival is close to what models predict. The analysis to subtract the background fluxes of magnetospheric and atmospheric particles is still in progress. The hope of this experiment is to investigate the noble gas isotopic ratios of this interstellar sample of matter which originated outside the solar system.

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N91-25016

ATOMIC OXYGEN AND ULTRAVIOLET RADIATION MISSION TOTAL EXPOSURES FOR LDEF EXPERIMENTS

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ABSTRACT

An analytical treatment of the effect of thermal molecular velocity on spacecraft atomic oxygen flux is presented. The analysis leads to a closed form equation that incorporates the effects of atmospheric temperature, number density, spacecraft velocity and incidence angle on AO flux. The effects of atmospheric rotation, solar activity, and geomagnetic index on AO flux are also included in a computer model. Data developed with the model are presented for the LDEF spacecraft. The results incorporate variations in the defining environmental and orbital parameters of the spacecraft over its near 6-year orbital Flight.

Cumulative ultraviolet solar and albedo exposures have been calculated based on results from the Solar Illumination Data Package prepared by NASA Langley.

To facilitate the definition of the environments for LDEF experiments, summary charts for both atomic oxygen and ultraviolet radiation exposure are presented.

N91-25017

MEASUREMENT OF THE O18 TO O16 ISOTOPE RATIO FOR CHARACTERIZING OXIDE SURFACE LAYERS ON LDEF SAMPLES

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ABSTRACT

Calculations indicate that measurement of the O_{18} to O_{16} isotope ratio in oxide layers formed on surfaces of LDEF samples would provide a powerful tool for distinguishing between layers formed at high altitudes and layers formed at low altitudes, as for example during retrieval of the satellite. In principle, this ratio may be used to date the formation of the oxide layers.

SPACE

ENVIRONMENTAL EFFECTS

MATERIALS

N91-25018

PRELIMINARY FINDINGS OF THE LDEF MATERIALS SPECIAL INVESTIGATION GROUP

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ABSTRACT

The retrieval of the National Aeronautics and Space Administration's Long Duration Exposure Facility (LDEF) from low-Earth orbit provided an opportunity for the study of long-duration space environmental effects on materials that is unparalleled in the history of the U.S. space program. The 5-year, 10-month flight of LDEF greatly enhanced the potential value of most LDEF materials, compared to that of the original 1-year flight plan. NASA recognized this potential by forming the LDEF Space Environmental Effects on Materials Special Investigation Group (MSIG) to address the expanded materials analysis opportunities available in the LDEF structure and on experiment trays, so that the combined value of all LDEF materials data to current and future space missions would be addressed and documented.

This paper presents the charter and scope of MSIG activities, followed by an overview of the preliminary MSIG observations. These observations of low-Earth orbit environmental effects on materials were made in-space during LDEF retrieval and during LDEF tray deintegration. Also presented are initial findings of laboratory analyses of LDEF materials. Included are effects of individual environmental parameters: atomic oxygen, ultraviolet radiation, meteoroid and debris impacts, thermal cycling, vacuum, and contamination, plus combined effects of these parameters. Materials considered include anodized aluminum, polymeric- and metal-matrix composites, polymer films, silvered Teflon thermal blankets, and a white thermal control paint. MSIG plans for further evaluations and data basing will be addressed.

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NASS 31647
1560
p. 1

N91-25019

CHEMICAL CHARACTERIZATION OF SELECTED LDEF POLYMERIC MATERIALS

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Abstract

The chemical characterization of selected polymeric materials which received exposure on the Long Duration Exposure Facility is reported. The specimens examined include silvered fluorinated ethylene propylene (FEP) teflon thermal blanket material, polysulfone, epoxy, and polyimide matrix resin/graphite fiber reinforced composites, and several high performance polymer films. These specimens came from numerous LDEF locations and, thus, received different environmental exposures.

The results to date of infrared, thermal, x-ray photoelectron, and various solution property analyses have shown no significant change at the molecular level in the polymer that survived exposure. However, scanning electron and scanning tunneling microscopies show resin loss and a texturing of the surface of some specimens which resulted in a change in optical properties. The potential effect of a silicon-containing molecular contamination on these materials is addressed. The possibility of continued post-exposure degradation of some polymeric films is also proposed.

N91-25020

ABS. ONLY
11861
P. 1

PRELIMINARY INVESTIGATION OF THIN FILM POLYMERS EXPOSED TO LOW EARTH ORBIT

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ABSTRACT

Texas A&M University placed an experiment on board the LDEF satellite which consisted of 22 polymeric samples. A majority of these samples are thin films proposed for use in construction of long duration scientific balloons. In addition to the thin films some fibrous ropes were also included in the specimens to be exposed. The objective of this research is to determine the loss in strength, the change in radiative properties, and the general morphological changes in the materials due to prolonged exposure to atomic oxygen and high levels of UV radiation. Since the LDEF mission was extended by almost 5 years, our research objectives also include development and verification of computer simulations and earth based experimental reproductions of the low earth orbit environment.

The thin films included on the experiment were of three basic materials: polyethylene, polyester, or nylon. These materials ranged in thickness from 0.35 mil. to 1.0 mil. Some of the thin films were of a composite nature being reinforced with such material as kevlar or nylon. The fibrous ropes were constructed of kevlar and nylon.

A number of different tests are to be performed on the available specimens. The Texas Eastman Co. is working in conjunction with the primary investigators to characterize the properties of the thin film specimens. Absorptivity, emmisivity, reflectivity, and transmissivity are among the radiative properties that are being examined. Also, Fourier Transform Infrared Spectroscopy has been conducted to detect any oxidation, chemical contamination, or crosslinking of the specimens. The dynamic mechanical response of the specimens are characterized from 0.1 to 100 rad/s and temperatures from -150° to 100°C.

Preliminary results will be discussed. Dynamic mechanical testing of a 0.92/0.92 mil. polyester laminate film has indicated that the modulus loss of the exposed specimens may be very small. When the storage modulus of the exposed specimen was compared to the storage modulus of the control specimen over a temperature range of -150° to 100° there was very little change. Fourier Transform Spectroscopy performed on the same exposed material indicated crosslinking of the polyethylene which was verified by an increase in the storage modulus above the glass transition temperature. Optical microscopy of the sample showed micrometeoroid strikes and contamination in spots by what is thought to be silicon outgassed from a nearby experiment.

549-27
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P.1

N91-25021

STUDY OF BALLOON AND THERMAL CONTROL MATERIAL DEGRADATION ABOARD LDEF

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ABSTRACT

The initial results of analysis performed on a number of polymeric materials which were exposed aboard the Long Duration Exposure Facility (LDEF) are discussed. These materials include two typical high altitude balloon films (a polyester and a polyethylene) and silver-backed Teflon® from thermal control blanket samples. The techniques used for characterizing changes in mechanical properties, chemical structure and surface morphology include FTIR, SEM and dynamic mechanical analysis.

S50-27
NBS ONLY
N91-25022
11863
P.1

THE INFLUENCE OF FLOWING AFTERGLOW EXPOSURE ON THE DEGRADTION OF VARIOUS POLYMERIC MATERIALS

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ABSTRACT

Changes in polymer properties which result after exposure to the atomic oxygen-rich environment of a flowing afterglow are presented. Dynamic mechanical and FTIR spectra as well as SEM micrographs were employed to monitor variations in mechanical properties and chemical and physical structure. Polymers analyzed include polystyrene, PEKK, and a polyester.

N91-25023

CHEMICAL ANALYSIS OF METAL AND POLYMER SURFACES ON THE FRONT AND REAR OF LDEF

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ABSTRACT

The University of Alabama in Huntsville experiment A0114 contained 128 solid surface samples, half of which were exposed on the front and half on the rear of LDEF. Each sample is being subjected to a battery of analysis methods. In this poster, details of x-ray photoelectron (XPS) spectra, Auger electron spectra, FTIR and ATR infra-red spectra and high resolution profilometry and SEM imagery will be presented from a selection of metal and non-metal surfaces. Effects of contamination (in Space and subsequent to flight) and of UV are observed in addition to atomic oxygen effects.

Experiment No. A0114

N91-25024

LEO SPACE ENVIRONMENTAL EFFECTS: TRW LDEF EXPERIMENTAL TRAYS

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Abstract

Comprised of two identical trays, the TRW LDEF experiment (A0054) provided a unique opportunity to study long term space environmental effects on a variety of materials exposed to two different space environments. The leading edge tray (location D-10) "saw" micrometeors and anthropogenic space debris, UV radiation, and energetic (4 eV nominal) atomic oxygen. In contrast, the trailing edge tray (location B-4) was exposed to UV and micrometeors but saw relatively little, if any, space debris fluence and no energetic atomic oxygen. The striking difference in appearance of the two experimental trays is directly attributable to the nonuniformity of the space environment about the LDEF. It is estimated that the majority of the erosion to the Kapton polyimide dielectric material occurred during the last month on orbit due to the sharply nonlinear increase in atomic oxygen number density as orbital altitude decayed over the life of the mission. Scanning electron micrographs reveal a morphology resulting from the off-normal impingement angle of the atomic oxygen flux. Particle impact sites, both micrometeors and space debris, were documented on five types of surfaces: 1) layered tapes and polymer films, 2) fiberglass composites, 3) aluminium plate, 4) unsupported polymer films, (Kapton polyimide), and 5) photovoltaic cells. The impact sites cataloged on the TRW experiment matched preflight predictions of an 8:1 ratio of leading to trailing edge fluence, with size and frequency distributions consistent with available particle environment models and flight data. Thermal property measurements of thermal control blanket/dielectric materials and paints revealed significant differences attributable to differences in the space environment seen by leading and trailing edge trays. Energetic atomic oxygen and UV radiation are believed to be the most significant contributors to the thermal property changes observed. Evidence of spacecraft self-contamination was seen in the form of photopolymerized and oxidized outgassing deposits at the edges of tapes and films, and the so-called "nicotine stain" (identified as an oxidized form of silicone) documented for the first time on the LDEF.

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N91-25025

INTERACTIONS OF ATOMIC OXYGEN WITH MATERIAL SURFACES IN LOW EARTH ORBIT: PRELIMINARY RESULTS FROM EXPERIMENT A0114

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ABSTRACT

The UAH atomic oxygen experiment consisted of two trays (one-sixth of an LDEF tray each) of 64 one inch diameter solid samples. One tray was placed on the leading edge C9 and one on the trailing edge C3 of the spacecraft. Half of each sample was covered to provide a control. Thus it was intended that the effects of atomic oxygen and solar UV irradiation on the surface properties of each material could be distinguished from each other and from the effects of aging. Sixteen of the samples were placed on a thermally isolated plate of highly polished aluminum, while the main plate was coated with the thermal control coating S13-GLO. Though the experiment was entirely passive it was hoped that effects of thermal activation might be observed, if present. The plates were expected to stabilize at temperatures differing by 20 - 30°C. The experiment also carried a device to measure the spacecraft altitude (reported elsewhere at this meeting) and several oxygen atom reflectometers which have not been analyzed to date.

The samples included thin films of metals Os, Ir, Pt, Ni, W, Mo, Al, coated onto fused silica optical flats, metal carbides (WC, SiC), solid carbons of various types, eight polymers and some other coatings of various types.

Analysis is essentially complete using stylus profilometry with the high sensitivity Talystep and the lower sensitivity Talysurf machines. Though the integrated fluence of O atoms on LDEF was 30 times that on previous missions, etch depths on polymers such as the polyimide Kapton show excellent agreement with extrapolations from previous flight data . Some new effects are however observed. We have shown in a previous experiment on STS-8 that profilometry of this kind can show steps of 50 Å (for example those due to oxide film growth on metals) and this is now the preferred method for estimating etch depth (or mass loss) of erodible substances. We have also begun surface analysis of the materials using FTIR, SEM, XPS and Auger electron spectroscopies.

Experiment No. A0114

554-27
ABS Only
11867
p. 1

N91-25026

LDEF EXPERIMENT A0034 INTERIM RESULTS

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ABSTRACT

The passive LDEF Experiment A0034, "Atomic Oxygen Stimulated Outgassing," consisted of two identical one-sixth tray modules, exposing selected thermal control coatings to atomic oxygen and the combined space environment on the Leading Edge and, for reference, to the relative "wake" environment on the Trailing Edge. Optical mirrors were included adjacent to the thermal coatings for deposition of outgassing products. Ultraviolet grade windows and metal covers were provided for additional assessment of the effects of the various environmental factors. Preliminary results indicate that orbital atomic oxygen is both a degrading and optically restorative factor in the thermo-optical properties of selected thermal coatings. There is evidence of more severe optical degradation on collector mirrors adjacent to coatings that were exposed to the RAM-impinging atomic oxygen. This evidence of atomic oxygen stimulated outgassing is discussed in relation to alternative factors that could affect degradation. The general effects of the space environment of the experiment hardware as well as the specimens are discussed.

S55-72
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p. 1

N91-25027

ATOMIC OXYGEN UNDERCUTTING OF LDEF ALUMINIZED KAPTON MULTILAYER INSULATION

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ABSTRACT

Atomic oxygen undercutting is a potential threat to vulnerable spacecraft materials which have been shielded with an atomic oxygen protective coating. This is due to atomic oxygen attack of oxidizable materials at microscopic defects in the protective coatings which occur during fabrication and handling, or from micrometeoroid and debris bombardment in space. An aluminized Kapton multilayer insulation (MLI) sample which was flown on the leading edge of the Long Duration Exposure Facility (LDEF) has been used to study low Earth orbit (LEO) directed ram atomic oxygen undercutting. Cracks in the aluminized coatings located around vent holes provided excellent locations for evaluation of atomic oxygen undercutting. The undercutting profiles have been compared to Monte Carlo models which predict LEO ram atomic oxygen attack. The shape of the undercut profile was found to vary with the crack width, which is proportional to the number of atomic oxygen atoms entering the crack. The resulting atomic oxygen undercut profiles which occurred on LDEF indicated wide undercut cavities in spite of the fixed ram orientation. Potential causes of the observed undercutting profiles will be presented. Implications of the undercutting profiles relevant to Space Station Freedom will also be discussed.

S56-27
ABS ONLY

N91-25028

PRELIMINARY RESULTS FOR LDEF/HEPP THERMAL CONTROL SAMPLES

11869
P.1

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ABSTRACT

Among the numerous experiments flown, the late Ben Siedenberg of the NASA Goddard Space Flight Center's Thermal Engineering Branch, placed sixty-five (65) 1-inch by 12-inch strips of Kapton coated with various black paints, white paints, clear coatings, and thin film oxides at three locations on the LDEF. These coatings were divided into 5 sets. Two sets were flown in the ram direction on top of the MLI blanket of the Cascade Variable Conductance Heat Pipe Experiment (CVCHPI tray F9). These thermal control samples saw UV, protons, and atomic oxygen. Two other sets were flown on top of the MLI blanket of the Low Temperature Heat Pipe Experiment (HEPP tray F12) perpendicular to the ram direction and saw UV, protons and much less atomic oxygen. The last 13 samples were taped to the perimeter of the HEPP power tray (H1) on the space end of the satellite. These samples also saw UV, protons, and some atomic oxygen. Of the two sets of samples on the CVCHPI tray, one was lost in space before retrieval due to atomic oxygen erosion of the Kapton tape which held the samples to the MLI blanket. The rest were recovered with varying degrees of degradation and erosion. This paper presents the solar absorptance and normal emittance measurements made on the 52 remaining samples. A comparison with control samples retained under laboratory conditions is also presented.

Experiment No. S1001

S57-27
AIAA-91-0477
11870
p.1

N91-25029

ATOMIC OXYGEN INTERACTIONS WITH FEP TEFLON AND SILICONES ON LDEF

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ABSTRACT

The LDEF spacecraft represents the first controlled unidirectional exposure high-fluence atomic oxygen on fluorinated ethylene propylene (FEP Teflon) and silicones. The atomic oxygen erosion yield for FEP Teflon was found to be significantly in excess of previous low fluence orbital data and is an order of magnitude below that of polyimide Kapton. LDEF FEP Teflon erosion yield data as a function of angle of attack will be presented.

Atomic oxygen interaction with silicone polymers results in crazing of the silicones as well as deposition of dark contaminant oxidation products on adjoining surfaces. Documentation of results and possible mechanistic explanations will be presented.

N91-25030

VUV-INDUCED DEGRADATION OF FEP TEFLON ABOARD LDEF

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P. 1

ABSTRACT

Examination of fluorinated ethylene propylene (FEP) copolymer materials recovered from the Long Duration Exposure Facility (LDEF) reveals differing damage characteristics on leading edge (ram-facing) versus trailing edge (wake-facing) surfaces. Silver/Teflon (Ag/FEP) thermal control materials on ram-facing surfaces of LDEF exhibited obvious degradation, with an apparent increase in diffuse light scattering, whereas identical materials on the wake-facing surfaces showed little apparent damage with cursory inspection. Microscopic examination of both types of surfaces reveals the nature and extent of environment-induced degradation of the materials. The ram-facing surfaces were clearly eroded by atomic oxygen impingement, while the wake-facing material developed a thin, highly-embrittled surface layer. A similar brittle surface layer has been generated in the laboratory via vacuum ultraviolet (VUV) irradiation of FEP. Surface morphologies for these materials have been characterized by Atomic Force Microscopy (AFM). Spectroscopic data including Fourier Transform Infrared (FT-IR) and Electron Spin Resonance (ESR) identifies intermediate and product species within the degraded material. These observations provide a basis for the formulation of interaction mechanisms for degradation and implications for longer-term performance of FEP materials in space.

N91-25031

SPACE ENVIRONMENTAL EFFECTS ON SILVERED TEFLON THERMAL CONTROL SURFACES

S39-27
ABS. ONLY
11872
p.1

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ABSTRACT

Cumulative space environmental effects on Ag/FEP were a function of exposure orientation. Samples from nineteen silvered Teflon (Ag/FEP) thermal control surfaces recovered from LDEF have been analyzed to determine changes in this material as a function of position on the spacecraft. Although solar absorptance and infrared emittance of measured thermal blanket specimens are relatively unchanged from control specimen values, significant changes in surface morphology, composition and chemistry were observed.

All Ag/FEP surfaces exposed to atomic oxygen flux (rows 7-11), irrespective of exact angle, had a uniform cloudy appearance due to surface erosion. Scanning electron microscopy (SEM) showed a surface topography with sharp peaks and valleys, while x-ray photoelectron spectroscopy (XPS) detected a surface composition corresponding to contamination-free FEP, with less than 1 mole % oxygen.

Ag/FEP samples from rows 2 and 4, which flank the trailing edge row 3, had a nonuniform appearance, with alternating clear and cloudy bands. SEM imaging showed an intriguing variety of surface texturing in the cloudy areas, with surface wrinkling and puckering being most prevalent. XPS showed these surfaces to be contaminated nonuniformly with moderate to heavy concentrations of Si, O, C, N and S. Ultraviolet irradiation and thermal cycling (< 0°C) are presumed to be the dominant environmental factors.

The row 1, 5 and 6 samples, which are at larger angles to the trailing edge but not exposed to atomic oxygen flux, showed little or no texture development, and no surface contamination except low oxygen (which could be due to post-flight atmospheric exposure). XPS analysis does show significant degradation of the surface FEP on these rows, which we attribute primarily to UV radiation. The surface features are consistent with FEP molecular weight degradation, branching and crosslinking through free radical reactions, which can also be induced by x-ray or high energy electron irradiation.

We hypothesize that the FEP surfaces on LDEF are degraded by UV exposure at all orientations, but that the damaged material has been removed by erosion from the blankets exposed to atomic oxygen flux and that contamination is masking the damage on the trays flanking the trailing edge.

N91-25032

RESULTS OF EXAMINATION OF SILVERED TEFLON FROM THE LONG DURATION EXPOSURE FACILITY

S60-27
NSC 3447
11873
p. 1

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ABSTRACT

Pieces of silvered teflon thermal control blanket from seventeen locations on the Long Duration Exposure Facility (LDEF) have been provided to the MSIG for study. Results of measurements of surface texturing, and mechanical, electrical and thermal properties will be presented. Photos of the blankets, SEM pictures, IR spectra and surface analysis results will be presented. Contamination issues relative to performance of the blankets will be discussed. The variation in measured properties will be reported as a function of exposure conditions.

N91-25033

PRELIMINARY INVESTIGATIONS INTO UHCRE THERMAL CONTROL MATERIALS

S61-27
ABS 31447
11674
p.1

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ABSTRACT

This paper presents, in the first instance, an overview of the initial work which has been done in the ESTEC Materials and Processes Division to evaluate the effect of space environment on the thermal blankets of the Ultra-Heavy Cosmic Ray Nuclei Experiment (UHCRE) :
1. Preliminary survey of the perforation of the two-thirds of the thermal blanket returned to ESTEC.
2. Thermo-optical properties and thickness recessions of three samples cut from each of the third centre part of the 16 thermal blankets were measured and effects of environments, i.e.: sun illumination and atomic oxygen fluences, evaluated.
3. Contamination has been analysed on trays, external blanket and internal aluminised Kapton foil by IR technique and SEM/EDX examination.
4. The pattern of contamination on the Al Kapton foils has been observed, sketched and related to atomic oxygen flow.
5. LDEF yaw angle misorientation has been evaluated from the contaminated areas visible on some of the trays.

Then, impacts of micrometeoroids and space debris in spare flight thermal blanket have been experimentally simulated by means of the plasma acceleration facility of the TU Müchen and the EMI light gas gun acceleration facilities. Glass, steel and aluminium projectiles with sizes between about 50 µm and 1 mm have been accelerated in a velocity range between 2 km/s and 10 km/s. Circular shock-induced delamination zones surrounding impact locations in the foil have been obtained.
Relations between penetration/perforation hole characteristics and projectile parameters have been established.

Experiment No. AO178

N91-25034

EFFECTS OF LDEF FLIGHT EXPOSURE ON SELECTED POLYMERIC FILMS AND THERMAL CONTROL COATINGS

S62-27
ABS ONLY
11875
P. 1

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ABSTRACT

The characterization of polymeric films and thermal control coatings which were exposed for 5 years and 10 months and only 10 months to the LEO environment is reported. Changes in solar absorptance, thermal emittance, and transmission are compared to laboratory control specimens. Sputter-deposited metallic coatings are shown to eliminate atomic oxygen erosion of resin matrix composite materials. The effects of long-term atomic oxygen exposure to metallized FEP Teflon film are characterized. Chemical characterization of polymeric films including infrared, thermal, and ESCA indicate that although surface erosion occurs, the molecular structure of the basic polymeric film had not changed significantly in response to this exposure.

EXPERIMENT NO. S0010

N91-25035

THERMAL CONTROL SURFACES EXPERIMENT (S0069) INITIAL MATERIALS EVALUATION

S63-07
NASA only
1187c
p.1

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ABSTRACT

The behavior of materials in the space environment and our understanding of this behavior continues to be a limiting technology for spacecraft and experiments. The Thermal Control Surfaces Experiment (TCSE) aboard the LDEF is the most comprehensive experiment flown to study the effects of the space environment on thermal control surfaces. Selected thermal control surfaces were exposed to the LDEF orbital environment and the effects of this exposure measured. The TCSE combined in-space optical measurements with pre- and post-flight analyses of flight materials to determine the effects of long term space exposure.

Many of the TCSE samples underwent significant changes in appearance as well as optical and mechanical properties. Because of the synergistic effects of the constituents of the space environment, some materials underwent greater changes than expected where others underwent less.

The TCSE experiment objective, method and measurements will be described along with the results of the initial materials analysis. Flight and ground measurements of flight materials will be presented. Photographs of the flight samples will also be presented to show physical changes.

Experiment No. S0069

N91-25036

UNUSUAL MATERIALS EFFECTS OBSERVED ON THE THERMAL CONTROL SURFACES EXPERIMENT (S0069)

S64-27
AGS. ONLY
11277
P. 1

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ABSTRACT

A number of unusual effects were observed on the Thermal Control Surfaces Experiment (TCSE) test samples, front cover, and structural components. These include induced UV fluorescence, the migration and degradation of KRS-5 materials, Atomic Oxygen (AO) effects, contamination, texturing, discoloration, and meteoroid/debris impacts. LDEF mission induced fluorescence was observed on several TCSE samples. Similar fluorescence was observed on LDEF leading and trailing edge materials from Experiment AO114 (Gregory, Peters).

KRS-5 infrared transmitting window material was utilized on the TCSE as passive contamination monitors. The KRS-5 samples suffered severe surface damage during the LDEF mission. Some of the material migrated onto its holder by either vapor transport or physical bonding.

Atomic oxygen damage radically changed the appearance of silver Teflon thermal control surfaces from specular to diffuse. In addition, the silver Teflon on the TCSE cover degraded significantly because of acrylic adhesive contamination. This contaminaion occured during application of the silver Teflon sheet material when the bonding adhesive was spread over its exposed surface. The suppliers recommended cleaning procedures only smeared the adhesive leaving a residue not visually obvious at the time. Another interesting aspect of the AO effects on silver Teflon is the difference in the damage for material applied over aluminum and over fiberglass substates.

Some interesting and intriguing shadowing effects occured on the sides of the TCSE tray which correlate to the LDEF RAM direction. Similar shadowing was evident inside the TCSE tray.

Experiment No. S0069

N91-25037

S65-27
NASA-CR-187138
p.1

SPACECRAFT THERMAL CONTROL COATINGS
(A0 138-6)

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ABSTRACT

The experiment A0 138-6 was located on the trailing edge of LDEF as part of the Experiment FRECOPA. It was purely passive in nature : material specimens 2 x 2 cm, independently mounted in sample-holders with their surface in the same reference plane,were exposed to space. Thirty samples were set in a canister which was opened in space a few days after LDEF deployment and closed still in orbit ten months later; twenty four samples were directly exposed to space for the total flight duration (preflight handling, shuttle bay environment, separation from shuttle, shuttle environment, LEO environment, docking, descent, transfer to KSC). Materials include paints (conductive or not), SSMs, polymeric films, surface coatings, composite materials, metals.

After sample retrieving, inspection and measurements were carried out in atmospheric laboratory conditions on each sample : observation with binocular lenses and SEM, spectral reflectance and transmittance using an integrating sphere in the wavelength range 250 to 2500 nm, emissivity by the means of a Gier & Dunkle portable equipment, ESCA measurements on some selected specimens.

The results show that for some materials the degradation was higher for samples in the canister than for those directly mounted at the surface of the tray; contamination problems having been ruled out, the higher temperature experienced by the samples inside the canister probably explains this phenomenon. The results from flight have been compared to laboratory results obtained in space simulation conditions when available; as a general statement, a good concordance is observed for all samples not in the canister so long as air recoveries are taken into account.

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N91-25038
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11879
p. 1

THERMAL CONTROL MATERIALS

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ABSTRACT

The LDEF M0003-5 Thermal Control Materials Experiment contains numerous thermal control coatings, metallized and nonmetallized polymeric films, adhesives, OSR's, and metallic foils. The materials were located on the leading and trailing edges of the satellite, therefore exposed to two different low earth orbital environments. Many specimens received a total exposure period of 5.75 years and others received a limited exposure of 0.9 years to the complete environment. On orbit and post flight photographic records will be presented. This paper will discuss the material's physical and optical performance as a function of location and duration of exposure. Data concerning specimen condition, degradation, contamination, optical reflectance and transmittance will be discussed. The effect of atomic oxygen erosion on specific materials will also be presented. The performance of adhesive bonds with polymeric films will be reviewed.

N91-25039

RESULTS OF EXAMINATION OF THE A-276 WHITE AND Z-306 BLACK THERMAL CONTROL PAINT DISCS FLOWN ON LDEF

S67-27
ABS 20147
11510
p.1

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ABSTRACT

Measurements of optical properties and surface characterization of paint discs on selected tray clamps have been carried out and are reported here. Analysis shows the loss of organic binder for those specimens exposed to atomic oxygen. A visibly darkened layer up to 2 microns thick exists on the outer surfaces of specimens exposed only to soiar radiation. Properties of ground control specimens and flight specimens, as a function of spacecraft location, will be reported Representative examples from a photomicrograph survey and SEM examination will be shown.

N91-25040

ION BEAM TEXTURED AND COATED SURFACES EXPERIMENT (IBEX)

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ABSTRACT

Future spacecraft relying on thermal control surfaces or solar thermal power generation will be subjected to the totality of the near-earth space environment. The combined effects of the near-earth environment may be synergistic and could cause degradation not observed in ground based simulation studies. In situ exposure to the space environment of various candidate materials is required to evaluate material, optical, and electrical property durability, so that a choice of surface materials can be made with respect to optical and/or electrical performance, durability and contamination protection requirements. With this in mind, the IBEX, with 36 samples of various materials, was placed aboard the LDEF. Twenty-seven of the samples had surfaces modified using ion beam technology, and nine were made up of commercially available materials. The materials are in some way useful in space power systems. The various types of materials tested included six categories: (1) ion beam structured surfaces suitable for solar-thermal (concentrator) or space radiators; (2) ion beam sputtered conductive coatings for thermal and space charge control; (3) solar reflector surfaces; (4) flexible thin film coatings and solar array blanket material for protection of spacecraft polymers; (5) painted and/or state-of-the-art solar thermal materials; and (6) micrometeoroid sensitive detector.

Data analysis to be presented include the optical properties of each surface before and after exposure to the space environment and the respective backup surfaces.

5-29-26
ABS ONLY
11882
p.1

N91-25041

ELLIPSOMETRIC STUDY OF METAL SAMPLES

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ABSTRACT

We have studied by variable angle spectroscopic ellipsometry both exposed and unexposed (shielded) portions of the surfaces of six different metal samples (aluminum, copper, nickel, tantalum, tungsten and zirconium) that had been mounted on the LDEF. The object of this study was to measure the change in the optical constants of the metals caused by exposure to the space environment. In spectroscopic ellisometry a monochromatic beam of plane-polarized light is reflected from the surface under study. The reflected light is elliptically polarized, in general, and the parameters of the ellipse can be analyzed in terms of the optical constants of the surface. In our experiment, the wavelength of the light was changed in steps of 200 Angstroms from 4000 to 8000 Angstroms, in other words from the near ultraviolet part of the spectrum to the near infrared, and the angle of incidence of the light was varied from 60 degrees to 80 degrees. Under these conditions the skin depth of a metal ranges from 50 Angstroms (copper) to about 500 Angstroms (Tungsten). The measured optical constants reflect changes in the morphology and stoichiometry of a surface layer to a depth of this order of magnitude. For all the samples examined in this manner the exposed and unexposed portions exhibited dramatically different optical properties. In order to determine whether the observed changes were caused by the impact of oxygen atoms encountered in flight we have set up an experiment in which samples identical to the original metal samples are exposed to a low-energy oxygen plasma in a microwave discharge chamber. We expect that the energy of the oxygen ions under these conditions will be about 10 electron volts, in other words about twice the impact kinetic energy encountered in space. Results of this experiment will be reported, as well as an analysis of the observed data in terms of surface layers of different compositions.

N91-25042

CONDITION OF CHROMIC ACID ANODIZED ALUMINUM CLAMPS FLOWN ON LDEF

570-26
NAS ONLY
11883
P. 1

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ABSTRACT

A survey of the condition of the chromic acid anodize(CAA) coating on selected LDEF tray clamps has been carried out. Measurements of solar absorptance and thermal emittance were carried out at multiple locations on both the space exposed and spacecraft facing sides of the clamps. Multiple clamps from each available angle relative to the ram direction were examined. The diffuse component of the reflectance spectrum was measured for a selected subset of the clamps. The thickness of the CAA was determined for a small set of clamps. Examples of variation in integrity of the coatings from leading to trailing edge will be shown.

N91-25043

PATTERNS OF DISCOLORATION AND OXIDATION BY DIRECT AND SCATTERED FLUXES, ESPECIALLY OXYGEN ON SILICON

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ABSTRACT

A number of interesting discoloration patterns are clearly evident on M0002-1 which resides on three faces of LDEF: front face, rear face, and earth face. Most interesting is the pattern of blue oxidation on polished single crystal silicon apparently produced by once-scattered ram oxygen atoms along the earth face. Most of the other patterns are seen in the NASA S13G/LO Thermal Control Paint. Also, severe oxidation of CR-39 polycarbonate occurred on the front face of LDEF, as expected. A complete explanation for the patterns has not yet been obtained. For example, all of the honeycomb structure outgassing holes have a small discoloration ring around them, but some of the rings are lighter, while most are darker, than the average paint color. The shadow cast by a suspended wire on the earth face surface is not easily explained by either solar photons or by "ram" flux. The shadow is a well defined white line and argues for a photon flux incident at 14 (+ or - 2) degrees off the normal to the front face (#9) assuming that photons caused the darkening in the paint. But solar UV photon fluxes occurred over a wide range of angles and, thus, should not produce a sharply defined white shadow. Additionally, the ram flux was not expected to occur at a 14 degree angle, reports to date put it at 8 degrees. Ram flux would produce a dark shadow, not the actual white shadow. Thus, the shadows and the dark/light regions cannot be consistently explained by solar UV paint-darkening modulated by ram flux oxygen bleaching of the paint. These results remain to be explained.

N91-25044

THERMAL-VACUUM EFFECTS ON POLYMER MATRIX COMPOSITE MATERIALS

5/2-27
ABS ONLY
11885
P. 1

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ABSTRACT

Results are presented on the thermal-vacuum response of a variety of fiber-reinforced polymer matrix composites that comprised the UTIAS experiment (AO 180) on the NASA LDEF satellite. The UTIAS experiment consisted of 62 tubes, a stainless steel calibration tube and 45 flat samples fabricated from epoxy matrix composites with graphite, boron and Kevlar® fiber reinforcements. A magnetic tape cassette-based data acquisition system was custom designed and constructed at UTIAS to monitor 16 channels of *strain* and *temperature* every 16 hours for the first year in orbit. The unit functioned flawlessly and yielded 557 data points that were used to construct thermal distortion curves as a function of elapsed time in orbit. Theoretical temperature-time predictions for this experiment are in excellent agreement with test data. Results also show quite clearly the effect of outgassing in the dimensional changes of these materials and the corresponding coefficients of thermal expansion. Finally, comparisons with ground-based simulation tests will be presented as well. Use of this data for design purposes will also be given.

N91-25045

ATOMIC OXYGEN EROSION OF POLYMER MATRIX COMPOSITES

S73-27
NASA ONLY
11886
P.1

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ABSTRACT

Results are presented on atomic oxygen erosion of circular tubes and flat plates fabricated from different epoxy matrix composites containing graphite, boron and Kevlar® fiber reinforcements. The UTIAS experiment (AO 180) was located at station D-12, at 90° to the LDEF leading edge which, by NASA estimates, was yawed about 8°~10° relative to the velocity vector. This resulted in enhanced atomic oxygen exposure at D-12, providing a total fluence of about 4×10^{20} atoms/cm^2. Thickness loss measurements have been obtained for both flat plates and cylindrical tubes. In the latter case, erosion profiles as a function of angular position around the tube will be shown based on SEM analysis. In addition, the effect of reflected atomic oxygen on erosion yield and surface morphology on back surfaces (not directly exposed to AO) will be graphically demonstrated. Erosion yields will also be compared with other space flight data for similar materials, and ground-based tests in the UTIAS AO simulator. The effect of angle of incidence on surface morphology, erosion profiles and thickness losses will be presented and the results correlated with simulator tests as well. Finally, the use of this data in the design of composite spacecraft structures will be discussed.

Part of this presentation will address the issue of micrometeoroid/debris impact distribution on the experiment. Photomicrographs of crater damage and spallation of a composite will be shown, with an assessment of how this information can be incorporated into structural design.

N91-25046

LONG DURATION EXPOSURE FACILITY EXPERIMENT M0003 DEINTEGRATION/FINDINGS & IMPACTS

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314-27
ABS. ONLY
11887
P. 1

ABSTRACT

The Aerospace Corporation LDEF Experiment M0003 consists of 19 subexperiments from the Aerospace Laboratories, DoD Laboratories and contractor organizations, and was designed to study the effects of the space environment on a large variety of spacecraft materials and components, both current and developmental. The experiment was housed in four LDEF trays and contained over 1200 specimens, two data systems, and two environment exposure control canisters. Nearly identical pairs of trays were located on the leading and trailing edges of LDEF. The materials in these trays span nearly all generic functions in spacecraft such as optics, thermal control, composites, solar power, and electronics. Effects of the space environment such as vacuum, ultraviolet, atomic oxygen, meteoroid and debris, thermal cycling and synergistic effects on various samples will be described, and summaries of the on board data will be presented.

N91-25047

LONG DURATION EXPOSURE FACILITY EXPERIMENT M0003 DEINTEGRATION OBSERVATIONS

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ABSTRACT

The four trays of the M0003 materials experiment on LDEF contained over 1200 test articles from 19 subexperimenters. The complete test article complement represented a broad range of materials, including thin film optical coatings, paints, polymer sheets and tapes, adhesives, and composites, for use in various spacecraft applications including thermal control, structures, optics, and solar power. During the deintegration of the subexperiments from the M0003 trays, all of the test articles were examined individually using bright field, dark field, and Nomarski light microscopy techniques. The condition of the test articles were photo-documented and observed global and anomalous effects were recorded for the benefit of the subexperimenters. Since, some subexperiments included duplicate test articles exposed for 3, 6, 9, and 68 month durations on both the leading and trailing edges, comparisons provide a valuable time history of degradation. The test articles and their compositions and locations on the M0003 trays will be listed and identified by subexperiment. The most interesting deintegration observations for the M0003 experimental test articles will be featured in this presentation.

N91-25048

SURVEY OF RESULTS FROM THE BOEING MODULES ON THE M0003 EXPERIMENT ON LDEF

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376-27
NAS Only
11287
P.1

ABSTRACT

The Boeing modules on the M0003 experiment included fiber optics, ceramic materials, a variety of electronic piece parts, composites and thermal control paints, fasteners, thin film lubricants, anodized surfaces, and adhesives. These materials were flown on the leading and trailing edge exteriors, and on the interior portions of M0003 providing exposure under three distinct environments. The condition of each of these material types will be described. Results of optical, surface, and mechanical properties will be presented.

N91-25049

EXPERIMENT M0003-10: ADVANCED COMPOSITES

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S77-24
AES. ONLY
11870
p.1

ABSTRACT

The Advanced Composites Sub-Experiment is a joint effort between government and industry with Wright Laboratory, Flight Dynamics Laboratory and The Aerospace Corporation, Materials Sciences Laboratory serving as experimenters. The experiment includes numerous metal matrix composites, primarily graphite fiber reinforced aluminum and magnesium, and several classes of graphite fiber reinforced organic matrix composites. The latter includes graphite/epoxy, graphite/polysulfone, and graphite/polyimide composites with and/or without various thermal control or protective coatings. Most of the composite samples were 3.5 by 0.5 in. strips. There were also a limited number of 1 in. diameter mirror samples and several graphite/aluminum, graphite/magnesium and silicon carbide/aluminum wires. The experiment included over 500 flight samples, mounted on the leading and trailing edges of LDEF, and a full complement of laboratory control samples. Preliminary results will be presented reviewing changes in the visual appearance of the samples, atomic oxygen erosion of the organic matrix composites, contamination effects, and the effects of micrometeorite impacts and thermal fatigue on the metal matrix composites.

N91-25050

RESULTS FROM ANALYSIS OF BOEING COMPOSITE SPECIMENS FLOWN ON LDEF EXPERIMENT M0003

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378-34
ABS. ONLY
11891
p. 1

ABSTRACT

Specimens of three selected organic/graphite fiber composite materials were flown on both the leading and trailing edges of LDEF. Additional sets of compression, tension, flexure, and lap shear specimens were flown on the trailing edge. A large T300/934 panel was flown on the leading edge. One quarter of this specimen was directly exposed to a near ram environment; each of the other three quarters were covered with a different thermal control paint. Results of mechanical, optical, and chemical analysis of the specimens will be presented Recession rates of the fiber and resin under atomic oxygen exposure have been estimated and will be reported.

N91-25051

LDEF - SPACE ENVIRONMENTAL EFFECTS ON MATERIALS: COMPOSITES AND SILICONE COATINGS

S19-24
REC. ONLY
1192
P.1

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ABSTRACT

The objective of the Lockheed experiment is to evaluate the effects of long term low Earth orbit environments on thermal control coatings and organic matrix/ fiber reinforced composites. Two diverse categories are reported here: silicone coatings and composites. For composites physical and structural properties have been analyzed; results are reported on mass/dimensional loss, microcracking, short beam shear, CTE, and flexural properties. The changes in thermal control properties, mass, and surface chemistry and morphology are reported and analyzed for the silicone coatings.

N91-25052

HIGH-TOUGHNESS GRAPHITE/EPOXY COMPOSITE MATERIAL EXPERIMENT

S80-24
NRC Only
NE13
p. 1

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ABSTRACT

This experiment was designed to measure the effect of near-space exposure on three mechanical properties of specially toughened 5208/T300 graphite/epoxy composite materials. The properties measured are elastic modulus, strength, and fracture toughness. Six toughness specimens and nine tensile specimens were mounted on an external frame during the time of the LDEF mission. Specimen variables include angle of adjacent plies and fraction of interlaminar contact, which is controlled by the fraction of finely spaced holes in Mylar film placed between the prepreg monolayers of the composite. Three identical sets of specimens were manufactured at the outset: the flight set, a zero-time non-flight set, and a total-time non-flight set. Owing to the significance of retaining outer surfaces in their pristine post-mission condition for as long as possible until surface studies could be completed, only very limited testing of specimens has been completed to date. These results will be reported.

Experiment No. A0019, Tray D12

N91-25053

EFFECTS OF LDEF FLIGHT EXPOSURE ON SELECTED POLYMER MATRIX RESIN COMPOSITE MATERIALS

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and

James Y. Shen
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ABSTRACT

The characterization of selected graphite fiber reinforced epoxy (934 and 5208) and polysulfone (P1700) matrix resin composite materials which received 5 years and 10 months of exposure to the LEO environment on the Long Duration Exposure Facility is reported. The changes in mechanical properties of ultimate tensile strength and tensile modulus for exposed flight specimens are compared to the three sets of control specimens. Marked changes in surface appearance are discussed, and resin loss is reported. The chemical characterization including infrared, thermal, and selected solution property measurements showed that the molecular structure of the polymeric matrix had not changed significantly in response to this exposure.

EXPERIMENT NO. AO134

N91-25054

EFFECT OF SPACE ENVIRONMENT ON COMPOSITE MATERIALS AND THERMAL COATINGS
(A0 138-9)

382-24
NES ONLY
11275
p. 1

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ABSTRACT

This paper presents the results on experiments located in one of FRECOPA canister on epoxy-matrix carbon fiber-reinforced composite materials, adhesives as well as thermal coatings. Only thermal coatings and some composite materials were exposed to direct space environment for the first year (the FRECOPA canister closed at the end of the first year before LDEF retrieval scheduled in 1986) while other materials (for mechanical and expansion tests) were located in the lower levels (subjected to only vacuum and thermal cycling).
In order to assess the degradation of materials after space aging, reference specimens were stored in clean room for the duration of LDEF mission and tested at the same time as the aged specimens (in order to have exactely the same test conditions).

The design of composite structures for satellites are mainly based on data from unidirectional laminates. The objective was to check them by testing different types of materials based on 914, code 87 and V108 epoxy matrices. Thermal expansion tests, tension tests at room temperature, flexture and interlaminar shear tests up to service temperature have been performed in dry conditions; no major change has been revealed.
To check the influence of potential change of coefficients of thermal expansion on multidirectional laminates, specimens representative of satellite antenna reflectors were included in the experiment. No major change has been revealed. In addition, on composites based on V108 epoxy resin and exposed to direct space environment, scanning electronic microscope examination has not revealed any erosion of the material.

Adhesives on tensile lap shear tests. The objective was to observe on two epoxy adhesives the effects of the thermal stresses due to the assembly of materials having different coefficients of thermal expension and the thermal cycling. The tested specimens have not exhibit any changes.

Thermal coatings. Optical solar reflectors and second surface mirrors bonded on aluminium and composite materials have been tested in terms of thermo-optical properties (solar absorptance, infrared emittance, specularity coefficient). Still, no major change has been found out.

N91-25055

EFFECT OF SPACE EXPOSURE OF SOME EPOXY MATRIX COMPOSITES ON THEIR THERMAL EXPANSION AND MECHANICAL PROPERTIES
(A0 138-8)

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ABSTRACT

The experiment objectives are :
- to detect a variation of the coefficient of thermal expansion (CTE) of composite samples
- to detect an evolution of mechanical properties
- to compare the behaviour of two epoxy resins

The Coefficient of Thermal Expansion

The CTE is measured by interferometric method in a vacuum chamber ($P<10^{-5}$ mmHg). Two values are given: one for the positive step and one for the negative step. The mean step of temperature is +24 C.

Mechanical tests

Inspections : - Visual inspections
- Micrography

Mechanical tests : The following mechanical tests are achieved on the samples:
- Interlaminar shear strength
- Flexural strength
- Flatwise tensile strength

Results :

CTE : We can see some variations of CTE on carbon/epoxy composites.
But the most important one is observed on the honeycomb aluminium sandwich :
$1.1\ 10^{-6}$ to $-0.3\ 10^{-6}\ C^{-1}$.

Visual test : We can see an erosion of the surface and some little cracks.

Mechanical : The flexural module of the VICOTEX 108 increases by 27%.
The honeycomb sandwich flatwise strength has a very large scattering values.
This has to be related to the CTE evolution.

N91-25056

EVALUATION OF LONG-DURATION EXPOSURE TO THE NATURAL SPACE ENVIRONMENT ON GRAPHITE-POLYIMIDE AND GRAPHITE-EPOXY MECHANICAL PROPERTIES

S84-24
AGS-ONLY
11897
P. 1

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ABSTRACT

Experiment AO175 involved passive exposure -- on oblique leading and trailing faces of LDEF -- of carbon-fiber-reinforced laminates of epoxy, bismaleimide, and polyimide resins. Post-flight evaluation included: optical examination of exposed surfaces, panel weight and distortion measurements, ultrasonic c-scan inspection, and conventional mechanical testing of coupons machined from the panels.

Todate only subtle differences have been noted between exposed and laboratory control specimens; some small differences in mechanical properties have been noted but these are attributed to small-population data scatter and variations in laminate quality, rather than to the space exposure.

N91-25057

"EFFECTS OF SOLAR RADIATION ON GLASS"

S35-37
NES. ONLY
11898
P.1

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ABSTRACT

The effects of solar radiation of selected glasses is continuing. Optical property degradation is being studied using UV-Vis spectrophotometry. Strength changes are being measured using a concentric ring bend test. Direct fracture toughness measurements using an indentation test are planned.

SPACE

ENVIRONMENTAL EFFECTS

SYSTEMS

N91-25058

SPACE AGING OF SOLID ROCKET MATERIALS

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SB6-28
ARS 91-7
11849
P.1

ABSTRACT

Solid rocket propellant and rocket motor components were aged in a vented container on the interior of the LDEF. This paper will present the results of aging IPSM-II/PAM-DII space motor components. Ballistic and mechanical properties of the space aged main propellant, igniter propellant and ignition system were compared with similar data from preflight and ground aged samples. Mechanical properties of the composite materials and bonded joints used in the motor case, insulation, liner, nozzle, exit cone, and skirt were similarly evaluated. The space aging results will be compared to data collected in a ground based vacuum aging program on similar components. The operation of the vacuum actuated venting valve and pressure actuated resealing of the container will also be addressed.

The materials tested showed no significant changes due to space aging. These results indicate that properly designed solid rocket motors can be expected to perform reliably after extended periods of exposure to a space environment.

Experiment No. P0005

N91-25059

AN OVERVIEW OF THE FIRST RESULTS ON THE SOLAR ARRAY PASSIVE LDEF EXPERIMENT (SAMPLE), AO171

S87-44
ABS ONLY
11900
P. 1

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ABSTRACT

Space environmental effects are visibly obvious on components of experiment AO171 which contained solar cells, composites, polymeric thin films, solar reflectors, protective coatings, metals, paints and elastomers. Micrometeoroid/space debris impacts were observed on all experiment elements. Luminescence of polymide, silicone and polyurethane materials occurred under black light examination. Outgassing of RTV511 occurred mainly as a results of insufficient thermal vacuum bakeout but contamination of surrounding areas was limited. For the most part, molecular contamination on the experiment was minimal. Particulate contamination was noted on all experiment elements. Solar cell power degradation was predominantly below 10%. Elastomers lost mass and discolored; composites showed evidence of atomic oxygen attack, and unprotected thin polymeric films eroded away. Atomic oxygen effects were dominant on UV and atomic oxygen vulnerable paints. Metals oxidized, and small changes in solar reflectivity were noted for SiO and SiO_2 coated solar reflectors.

N91-25060

EXPERIMENT M0003-4
ADVANCED SOLAR CELL AND COVERGLASS ANALYSIS, AN OVERVIEW

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ABSTRACT

The experiment consists of 51 coverglass samples and 12 solar cell strings. Sixteen (16) of the coverglass samples were on the leading edge and 16 on the trailing edge. An additional 16 samples were used as control samples and were not flown. The scenario for analysis was established for the coverglass as follows. A photographic and Namarski survey were taken. Selected sites were then analyzed using surface analysis techniques. The coverglass samples are now in the process of being analyzed in their "dirty" condition for optical transmission, reflectance and absorbance. The coverglass samples will then be cleaned and the residue analyzed. The filters will then be analyzed by probing through their layers to evaluate the multilayers used in their design. The solar cells have been visually inspected and photographed. Tape recorder data is being analyzed and selected cell strings are being evaluated for their electrical properties.

N91-25061

ADVANCED PHOTOVOLTAIC EXPERIMENT, S0014: PRELIMINARY FLIGHT RESULTS AND POST-FLIGHT FINDINGS

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ABSTRACT

The Advanced Photovoltaic Experiment (APEX) is an LDEF experiment designed to provide reference solar cell standards for laboratory measurements as well as to investigate the solar spectrum and the effects of long term exposure of solar cells to the LEO environment. One hundred and fifty-five silicon and gallium arsenide solar cells were flown with the appropriate instrumentation to periodically measure cell performance and temperature. Located on the leading edge of LDEF, in position E9, it also contained a Gulton PCM data acquisition system and an EPDS for data storage. An Eppley cavity radiometer, an Adcole digital solar angle sensor and a set of sixteen optical filters with silicon cell sensors were included in the experiment to measure solar insolation at the time of data acquisition and to select optimum measurement conditions.

This paper will detail the experimental objectives, the design employed to realize these objectives and the solar cells and instrumentation selected for the flight. A discussion of the the eleven months of flight data returned will be included. We will also present preliminary results from the post-flight analysis of the absolute cavity radiometer, the digital solar angle sensor, and the Barr Associates narrow bandpass optical filters. The initial findings of work to determine the chemical nature of contamination layers on APEX will also be presented.

N91-25062

DURABILITY EVALUATION OF PHOTOVOLTAIC BLANKET MATERIALS EXPOSED ON LDEF TRAY S1003

S90-44
NAS.21147
11903
p.1

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Several candidate protective coatings on Kapton and uncoated Kapton were exposed to the low Earth orbital (LEO) environment on the Long Duration Exposure Facility (LDEF) in order to determine whether the coatings could be used to protect polymeric substrates from degradation in the LEO environment. These materials are used for flexible solar array panels in which the polymer is the structural member that supports the solar cells and current carriers. Arrays such as these are used on the Hubble Space Telescope and will be used on Space Station Freedom. The coatings that were evaluated were 700 Å of aluminum oxide, 650 Å of silicon dioxide, and 650 Å of a 4% polytetrafluoroethylene-96% silicon dioxide mixed coating. All of the coatings evaluated were ion beam sputter deposited. Although the primary purpose of the coatings are as a barrier to prevent attack of the polymer by atomic oxygen, the effect of UV and micrometeoroid or debris impacts was also of great interest. Tray S1003 where these materials were exposed unfortunately received a very low atomic oxygen fluence (4.8×10^{19} atoms/cm^2). As a result, there was very little detectable change in mass for any of the samples including the uncoated Kapton. The surface of the uncoated Kapton, however, did show some grazing incidence texturing. There were also, significant changes in the solar absorptance of the coated samples. There was a 6-10% increase in solar absorptance for the silicon dioxide and aluminum oxide coated Kapton and a 3-5% increase for the mixed coating. Thermal emittance did not change significantly for the coated samples. Scanning electron microscopy revealed few micrometeoriod or debris impacts, but the few found indicated that the extent of damage or cracking of the coating around the defect site did not extend beyond a factor of 3 of the impact opening diameter. Although little can be said about the atomic oxygen durability of these coatings, there is some indication that UV may be detrimental to the optical properties of the oxide coatings but the addition of a small amount of fluoropolymer may help. Micrometeorid and debris impacts also do not seem to do as much damage as originally anticipated, which is of great significance for coated surfaces on spacecraft in LEO.

N91-25063

Soj-44
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11904
p.1

LONG DURATION EXPOSURE FACILITY (LDEF) RESULTS

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ABSTRACT

Thermal control coatings, solar cells and micrometeoroid capture cells have been flown on the LDEF-Experiment S 1002 to investigate the behaviour of these components under space conditions and to collect micrometeoroids and debris.
The experiment and the components to be investigated are described. The visual inspections, electrical and thermooptical measurements as well as chemical and metallurgical investigations conducted on the complete experiment as well as on single components are described, analysed and discussed. As a result flight data of interesting thermal control coatings and of solar cells in a low earth orbit as well as informations about micrometeoroid impacts are presented.

Experiment No. S 1002

N91-25064

LDEF SP-HVDE (SPACE PLASMA-HIGH VOLTAGE DRAINAGE EXPERIMENT POST-FLIGHT DATA ON SPACECRAFT LEAKAGE CURRENT AND DISCHARGE

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ABSTRACT

TRW designed and fabricated two identical SP-HVDE trays which were flown in the NASA LDEF (Long Duration Exposure Facility) for five and three-fourth years in the LEO (Low Earth Orbit) environment. The two TRW trays were placed with one near the leading edge and one near the trailing edge, and investigation has been performed to compare the environmental interactions on the dielectric samples of the two trays. Each experiment tray consists of six assemblies with 3-4 dielectric samples of varying thicknesses (i.e., 2 mils., 3 mils., and 5 mils.,) biased under +/-300 VDC, +/- 500 VDC, and =/- 1000 VDC. These samples were made of Kapton dielectric material bonded to the glass/epoxy substrate with Eccobond 57C, which is a 60 wt% silver loaded epoxy. The original objective has been successfully achieved by measuring the first in-flight long term average leakage current through 156 coulometers. Less than 5% anomalous behavior of the coulometers were found in the post-flight analysis.

The data reveal significant contrasts between leading-edge and trailing-edge trays for insulations of high voltage systems such as high voltage solar arrays. Two mil thick samples seem to generate lowest average leakage current for high voltage system insulation. The different trend of data points occurring at +/-1000 VDC compared to ground test data (Ref. 1) may be explained by the local ESDs (Electrostatic Discharges) observed over many surfaces of the dielectric samples for leading-edge tray data. These discharges inhibit further leakage current collection similar to the arcing phenomenon in ground test (Ref.1) by providing a shorting path from the Eccobond back end to the plasma ground. Further investigation is undertaken to better understand the relationship between local ESDs and the leakage current data, and the difference between flight and ground test data.

Evidence of local ESDs has been discovered over the dielectric materials possible due to the synergism of the M/D (Micrometeoroid/Debris) impacts. A detailed analysis of some dielectric samples was performed using a Cambridge S-360 SEM (Scanning Electron Microscope) and a Kevex EDS (Energy Dispersive X-Ray Spectroscope) system. Several light colored deposits were discovered scattered around the vicinity of central pits, which implies a volcanic eruption has been formed. The elemental composition of the light color deposits determined by EDS is mainly Ag. The source of Ag is from the Eccobond adhesive and the spraying of Ag through local ESDs may form a short to the leakage loop.

N. J. Stevens, et al., "Investigation of high Voltage Spacecraft System Interactions with Plasma Environments," NASA TM-78831, 1978.

N91-25065

LONG DURATION EXPOSURE FACILITY (LDEF) LOW-TEMPERATURE HEAT PIPE EXPERIMENT PACKAGE (HEPP)

593-34
AES Only
11906
p. 1

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ABSTRACT

This paper discusses the flight test results obtained with the Heat Pipe Experiment Package (HEPP). The HEPP was designed to demonstrate the performance of an ethane constant conductance heat pipe (CCHP) and an ethane heat pipe diode in micro-gravity. These heat pipes have a nominal operating temperature range of 140 to 250°K. Also, included in the HEPP is a Phase Change Material (PCM) canister which provides temperature stability through melting and freezing of the n-heptane PCM.

Flight data indicates that the HEPP cooled to a minimum of 190°K on a cyclic basis. The operation of the CCHP and the diode with a 1-watt heat load applied to each was demonstrated over the entire 13 month period of recorded data. However, the inability of the HEPP to cool below 180°K prevented the electronics from executing programmed test profiles. As a result transport tests and diode reverse mode tests were not conducted and of course the freezing and thawing of the PCM could not be achieved.

In addition to the flight data, the paper presents a comparison of pre-flight, flight and post-flight thermal performance.

Experiment No. S1001

N91-25066

RESULTS FROM THE CASCADED VARIABLE CONDUCTANCE HEATPIPE EXPERIMENT ON LDEF

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ABSTRACT

A Variable Conductance Heatpipe Experiment (CVCHPE) was successfully flown onboard the Long Duration Exposure Experiment (LDEF) and demonstrated temperature control better than ± 0.3°C during fifty days of on-orbit data collection in a widely varying external environment . The experiment used two series connected , dry reservoir variable conductance heatpipes which require no electrical power for operation. The heatpipes used a central artery design with ammonia working fluid and nitrogen control gas. The LDEF was in orbit for almost six years rather than the planned one year mission. Although no additional data was taken during this extended period , post-test data indicated that the set point drifted upward less than 1°C per year. There were significant changes to the appearance of all external thermal control surfaces primarily due to atomic oxygen degradation. These changes, though, had little effect of the CVCHPE performance.

N91-25067

LONG DURATION EXPOSURE FACILITY
Transverse Flat Plate Heat Pipe

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395-24
NBS ONLY
11908
1.1

ABSTRACT

The Transverse Flat Plate Heat Pipe is a thermal control device that serves the dual function of temperature control and mounting base for electronic equipment. In it's ultimate application, the heat pipe would be a lightweight structural member that could be configured in a platform or enclosure, and provide temperature control for large space structures, flight experiments, and equipment. The purpose of this experiment is to evaluate the zero-g performance of several heat pipe modules. Performance assessment will include: (1) the systems heat transport capability, (2) temperature drop between evaporator and condensor, (3) the ability to maintain temperature over varying duty cycles and environments. Additionally, performance degradation, if any, will be monitored over the length of the LDEF mission. The objective of this experiment is to demonstrate that a self-regulated heat pipe thermal control system can maintain hardware temperatures within tolerances of 10 degrees F or less with varying heat inputs , independant of vehicle/payload orientation.

Experiment No. S1005

N91-25068

POST -FLIGHT CHARACTERIZATION OF OPTICAL SYSTEM SAMPLES, THERMAL CONTROL SAMPLES, AND DETECTORS FROM LDEF EXPERIMENT M0003, SUB-EXPERIMENTS 6 AND 13

596-27
AIAS. 91-1
11109
p. 1

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ABSTRACT

Flight samples and control samples of optical and thermal control coatings have been measured for hemispheric reflectance and transmission. Data was recorded for wavelengths from .25 microns to 18 microns. The samples were exposed directly to the orbital environment, but were on the trailing edge of the LDEF satellite. Preliminary analysis shows no significant change in the reflectance or transmission values of most of the samples.

Post-flight tests of avalanche photodiodes have yielded results. The tests consist of measuring the following detector parameters: breakdown voltage for set values of reverse current, responsivity vs. bias voltage, noise equivalent power, and uniformity of photoresponse. The avalanche photodiodes were mounted on the leading edge of the LDEF satellite, but were shielded from the outside by a silver-coated teflon foil cover. Small puncture holes are present in the foil, probably caused by impact of particles in orbit. For most of the detectors, there has been no significant change in noise or response.

N91-25069

LDEF ACTIVE OPTICAL SYSTEM COMPONENTS EXPERIMENT

597-74
AES ONLY
11910
P. 1

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ABSTRACT

A preliminary report on the Active Optical Systems Components Experiment is presented. This experiment contained 136 components in a six-inch deep tray including lasers, infrared detectors and arrays, ultraviolet light detectors, light-emitting diodes, a light modulator, flash lamps, optical filters, glasses, and samples of surface finishes. The experimental results for those components which have been remeasured are briefly summarized. In general, changes in the component characteristics appear as much related to the passage of time as to the effects of the space environment, but organic materials and extreme- infrared reflectivity of black paints show unexpected changes.

NASA Contract Number NAS1-14654
Experiment Number S0050
LDEF Flight Position E5

N91-25070

Effects of Long-Duration Exposure on Optical System Components

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The optical materials and UV detectors experiment (SOO50-1) was a set of 18 optical windows, filters, and ultraviolet detectors. The optical specimens were all retrieved in excellent condition. No delamination or blistering of the filters occurred. No discoloration of the optical window materials occurred, but the MgF_2 window did experience roughing. The most notable degradation of the optics were the deposition of an organic film on the exposed surfaces. The film absorption was measured using a Fourier Transform Infrared spectrometer and a UV spectrometer. The 6 percent absorption at 3.4 μ corresponds to about 100 mgm/ft^2 of organic film. The UV absorption was almost 100 percent at 200 nm and about 50 percent at 380 nm.

N91-25071

EFFECTS OF LONG TERM EXPOSURE ON OPTICAL SUBSTRATES AND COATINGS (S0050-1)

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ABSTRACT

The experiment consisted of Fused Silica and Ultra Low Expansion (ULE(tm)) glass samples which were either uncoated or had high reflectance silver, antireflectance, or solar rejection coatings. A set of duplicate control samples was manufactured and stored in a controlled environment for comparison purposes. We will present data on the analysis of the contaminate deposited on the samples, micrometeroid impact, and the environmental effects on the substrate materials and coatings. Some results of particular interest are that the contaminate composition varied between different types of samples, fractures were incurred in the glass at the micrometeroid impact site, and no darkening of the ULE(tm) glass occurred due to the radiation exposure.

N91-25072

OPTICAL PERFORMANCE OF EXPOSED SOLAR CELL COVERS

S100-44
NASA SMAT
1993
1-1

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ABSTRACT

This paper discusses the characterization results of samples flown on the Long Duration Exposure Facility (LDEF). These samples included both coated and uncoated fused silica and ceria glass substrates used in the manufacture of solar cell covers. The coatings comprised a single-layer magnesium fluoride antireflection coating and an all-dielectric high-reflector multilayer coating centered at 350 nm. Samples were mounted on both the leading and trailing surfaces of the LDEF for exposure to the environment of space. The optical properties of the coatings will be compared to control samples which were stored on the ground during the LDEF Mission. Results of Auger Electron Spectroscopy and Rutherford Backscatter Spectroscopy measurements made on several of the coatings will be presented to explain the effects of space on the chemical composition of the coatings.

N91-25073

EFFECT OF SPACE EXPOSURE ON PYROELECTRIC INFRARED DETECTORS

SD1-27
ABS. ONLY
11917
p.1

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ABSTRACT

Twenty pyroelectric-type infrared detectors were flown onboard LDEF. The detector chips were of three different pyroelectric materials: lithium-tantalate, strontium-barium-niobate and triglycine-sulfide. The experiment was passive; no measurements were taken during the flight. Performance of the detectors was measured before and after flight. Postflight measurements revealed that detectors made of lithium-tantalate and strontium-barium-niobate suffered no measureable loss in performance. Detectors made of triglygine-sulfide suffered complete loss of performance, but so did the control samples of the same material. Repoling of the triglycine-sulfide failed to revive the detectors.

N91-25074

VACUUM DEPOSITED OPTICAL COATINGS EXPERIMENT
(A0 138-4)

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ABSTRACT

The aim of this experiment was to test the optical behaviour of 20 components and coatings subjected to space exposure. Most of them are commonly used for their reflective or transmittive properties in space borne optics. They consist in several kind of metallic and dielectric mirrors designed for the 0.12-10 microns spectrum, UV and NIR bandpass filters, visible and IR antireflecting coatings, visible / IR dichroic beam splitters, and visible beam splitter.

The coatings were deposited on various substrates such as glasses, germanium, magnesium fluoride, quartz, zinc selenide, kanigened aluminium. Several coating materials were used such as AL, Ag, Au, MgF2, LaF3, ThF4, SiO2, TiO2, ZrO2, Al2O3,MgO, Ge, ZnSe.

Five samples of each component were manufactured. Two flight samples were mounted in such a way that one was directly exposed to space, the other looking backwards. The same arrangement was used for the spare samples stored on ground in an identical box as the flight one, kept under vacuum during the LDEF mission. Endly one set of reference components was stocked in a sealed box under dry nitrogen atmosphere.

By comparing the pre and post flight optical performances of the 5 samples of each component it is possible to detect the degradations due to the space exposure.

N91-25075

S103-35
ABS. ONLY
11916
P. 1

RULED AND HOLOGRAPHIC GRATINGS EXPERIMENT
(A0 138-5)

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ABSTRACT

The Grating Department of INSTRUMENTS S.A Jobin Yvon Division has been interested by a participation on LDEF Experiment for the study of the behaviour of diffraction gratings, ruled replica, holographic and ion etched masters, with a long exposure to real space environment.

To separate the metallic coatings comportment, some mirrors have been added to the experiment.

To be free from grating senescence on ground, one set reference compounds have been stored.

To differenciate vacuum influences and sun illumination, cosmic dust and radiations incidences, two sets of compounds have been loaded, exposed and shaded type.

The investigation on possible damages have been operated according to the fundamental triple point of view of wavefront flatness, absolute efficiency and stray light level.

The stray light level evaluation as not been yet operated (April 1991).

The test results are encouraging.

Senescence on ground: none degradations have been observed on the reference type components.

Blank and groove distortion: none wavefront flatness deformations have been viewed for any type of gratings.

Vaccuum long duration stage (shaded type compounds): a very slight loose of reflectance power has been measured (lower than 3%) on both platinium (45 - 120 nm spectral range) and aluminium (220 - 600 nm spectral range) coatings. Any increase have been obtain with the platinium coated holographic master.

A notable degradation has been observed with aluminium coated ruled replica and ion etched master in the near UV region (220 - 300 nm spectral range), 10% light efficiency looses at 220 nm.

Sun illumination and space environment (exposed type compounds): we note a large loose of reflectance power in addition to shaded type on Pt and Al coatings, up to 20%.
This is also true with the gratings.

N91-25076

EXPOSURE TO SPACE RADIATION OF HIGH-PERFORMANCE INFRARED MULTILAYER FILTERS

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S104-27
AGS 3117 11917 p.1

ABSTRACT

The Reading experiment exposed IR interference filters and crystal substrates on identical earth facing and leading-edge sites of the LDEF. Filters mostly comprised multilayer coatings of Lead Telluride (PbTe)/II-VI on Germanium (Ge) and other substrates: crystals comprised CdTe, MgF_2, sapphire, quartz, silicon, and some softer materials. Identical control samples were maintained in the laboratory throughout.

The filters were novel in their design, construction and manufacture, and categorised *high-performance* because of their ability to resolve emission spectra of the important atmospheric gases for various purposes in remote sensing. No significant changes were found in the spectra of the hard-coated filters or in the harder crystals (the softer materials were degraded to an extent). By virtue of this well-documented and long exposure in LDEF the Qualification of the filter type is significantly improved for its future requirements.

N91-25077

PASSIVE EXPOSURE OF EARTH RADIATION BUDGET EXPERIMENT COMPONENTS LDEF EXPERIMENT AO-147: POST-FLIGHT EXAMINATIONS AND TESTS

SIDS-96
ABS ONLY
1/9/8
P.1

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ABSTRACT

The PEERBEC experiment of the LDEF mission was composed of sensors and components associated with the measurement of the Earth Radiation Budget from satellites. These components included the flight spare sensors from the ERB experiment which operated on the Nimbus 6 and Nimbus 7 satellites. The Nimbus 7 instrument is still returning data as of this date. The 10 solar sensors were mounted in LDEF tray B-8 along with 10 (non-ERB) interference filters supplied by Barr Associates. The 4 earth-flux sensors were mounted in LDEF tray G-12 on the earth facing end. A cavity radiometer, similar to channel 10C of Nimbus 7 was included as part of the Advanced Photovoltaic Experiment (APEX) which was mounted in LDEF tray E-9. While PEERBEC was a passive experiment APEX was active.

This report describes the experiment components and materials as well as the pertinent background and ancillary information necessary for the understanding of the intended mission and the results. The extent and timing of the LDEF mission brought the exposure from solar minimum between cycles 21 and 22 through the solar maximum of cycle 22. The orbital decay, coupled with the events of solar maximum, caused the LDEF to be exposed to a broader range of space environmental effects than had been anticipated. The mission spanned almost six years concurrent with the 12 year (to date) Nimbus 7 operations.

Here, we present preliminary information (1) on the changes in transmittance experienced by the interference filters, (2) on the results of retesting of the thermopile sensors, which appear to be relatively unaffected by the exposure and (3) the results of the recalibration of the APEX cavity radiometer. The degradation and recovery of the filters of the Nimbus 7 ERB will also be discussed relative to the apparent atomic oxygen cleaning which also applies to the LDEF.

N91-25078

TRANSMITTANCE MEASUREMENTS OF ULTRA VIOLET AND VISIBLE WAVELENGTH INTERFERENCE FILTERS FLOWN ABOARD LDEF

S106-27
NCS 01104
11917
P.1

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ABSTRACT

A set of ten interference filters for the UV and VIS spectral region were flown on the surface of LDEF Tray B-8 along with ERB components from The Eppley Laboratory. We report on transmittance changes and other degradation observed after return of the filters to Barr. Substrate, coatings and, where applicable, cement materials are identified. In general, all filters except those containing lead compounds survived well. Metal dielectric filters for the UV developed large numbers of pinholes which caused an increase in transmittance. Band shapes and spectral positioning, however, did not change.

N91-25079

SPACE ENVIRONMENTAL EFFECTS ON COATED OPTICS

507-74
ABS ONLY
11920
p. 1

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ABSTRACT

Several multilayer coated mirror designs developed for potential space applications were tested on LDEF along with single layer witness coatings deposited on fused silica and a coated CaF_2 window. Performance requirements included high mirror reflectivity, low absorption, low scatter, environmental durability, and radiation hardness. The designs were selected in screening tests using combined electron, proton and simulated solar UV radiation[1]. The purpose of the space test was to validate the above test results and determine the effects of atomic oxygen and contamination on mirror performance.

Results from timed exposures show that a Si based coating design that maintained stable reflectance in laboratory simulations also maintained stable reflectance in orbit. The reflectance of ZnS based designs, on the other hand, showed significant decreases in reflectance at the design wavelength due to to a shift of the high reflectance band to shorter wavelengths. The shift was observed on all three ZnS based mirror designs irrespective of location on LDEF (ie, leading or trailing edge). One possible explanation being pursued is that these mirrors experienced material loss during the space flight.

In addition to the above effect the ZnS designs that were mounted on the leading edge of the satellite showed prominent dendritic surface growth. Scanning electron microscopy and scanning auger spectroscopy measurements are in progress to determine the chemical composition of the dendrites.

1. " Natural and Induced Space Radiation Effects on Optical Coatings and Materials" Final Report on Contracts N00123-78-C-0989 and N60530-79-C-0263 to the Naval Weapons Center by L. B. Fogdall, et al of The Boeing Radiation Effects Laboratory. April 1981.

Experiment No. 7

N91-25080

LDEF FIBER OPTIC EXPOSURE EXPERIMENT

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SP03-74
AGS.3084
11921
P.1

ABSTRACT

Ten fiber optic cable samples of different types were exposed in low earth orbit for over 5 1/2 years on the Long-Duration Exposure Facility (LDEF). Four of the samples were mounted externally, and the remaining six were internal, under approximately 1/2 gcm^{-2} of aluminum. The experiment was recovered in January of 1990, and laboratory evaluation of the effects of the exposure has continued since. An increase in loss, presumed to be from radiation darkening, aging effects on polymer materials used in cabling, unique contamination effects on connector terminations, and micrometeoroid impacts were observed on some of the samples. In addition, the dependence of sample loss was measured as a function of temperature before and after the flight.

All cable samples were functional, and the best exhibited no measurable change in performance, indicating that conventional fiber optic cables can perform satisfactorily in spacecraft.

Experimental results obtained to date will be presented and discussed.

N91-25081

PRELIMINARY ANALYSIS OF WL EXPERIMENT # 701, SPACE ENVIRONMENT EFFECTS ON OPERATING FIBER OPTIC SYSTEMS

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S109-74
NRS ONLY
11922
P. 1

22 March 1991

ABSTRACT

A brief overview of the analysis performed on WL Exp #701 is presented, highlighting the successful operation of the first known active fiber optic links orbited in space. Four operating fiber optic links were exposed to the space environment for a period exceeding five years, situated aboard and external to the Long Duration Exposure Facility. Despite the prolonged space exposure to radiation, wide temperature extremums, atomic oxygen interactions, and micrometeorite and debris impacts[1], the optical data links performed well within specification limits. Early Phillips Laboratory tests and analyses performed on the experiment and its recovered magnetic tape data strongly indicate that fiber optic applications in space will meet with high success.

* Principal Investigator for WL Exp #701 (M0004)

1. D.S. McKnight, R.E. Dueber, and E. W. Taylor, "Space Debris and Micrometeorite Events Experienced by WL Experiment 701 in Prolonged Low Earth Orbit", 8 Jun 1990, accepted for publication by the Journal of Geophysical Research Space Physics, Sept 1990.

N91-25082

STUDY OF FACTORS DETERMINING THE RADIATION SENSITIVITY OF QUARTZ CRYSTAL OSCILLATORS (A0189)

SID-27
PAPER ONLY
11923
P.1

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ABSTRACT

Quartz resonators fabricated from two different grades of quartz material, selected because of their susceptiblity to radiation damage as determined by transmission electron microscopy (TEM), were tested prior to the LDEF flight. These resonators were then flown on the LDEF mission where they were exposed to the radiation environment of low earth orbit. Post-flight tests were then conducted to determine any differences in resonator performance caused by the space exposure. Results of the TEM analysis of the quartz material and pre- and post-flight measurements of the flight resonators and, of the space and ground based control resonators, will be presented. Further planned work on the TEM analysis of the quartz materials will also be outlined.

N91-25083

EFFECTS OF SPACE ENVIRONMENT ON SPACE-BASED RADAR PHASED-ARRAY ANTENNA; STATUS AND PRELIMINARY OBSERVATIONS

S111-32
ABS ONLY
11924
P. 1

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ABSTRACT

The overall objective of this experiment is to evaluate the effect of the space environment on Kapton films considered for the Grumman SBR Phased-Array Antenna. The most striking result is the overall good condition of the Kapton antenna planes and Kapton tensile specimens. This is largely attributable to the orientation of the Kapton (parallel and flush on the space end) and the stability of LDEF in orbit. Results on elongation and mechanical properties of the plain and fiberglass-reinforced Kapton will be described. Stress-dependent permanent deformation and some reductions in strain to failure were observed. Physical property testing of the materials is in progress. Electronic data acquisition and memory systems appeared to operate correctly, but functional tests have not yet been performed. An evaluation of the high voltage-plasma interaction data is underway. Some minor systems anomalies (e.g., fastener sheared during removal, strong odor inside electronics container) were noted. Other observations such as radiation, contamination, impacts, and orientation features of atomic oxygen erosion will be reported.

Experiment No. A0133

N91-25084

SYSTEMS SPECIAL INVESTIGATION GROUP OVERVIEW

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S12-23
AGS 3047
11925
1-1

ABSTRACT

The Systems Special Investigation Group (SIG) has undertaken investigations in the four major engineering disciplines represented in LDEF hardware: electrical, mechanical, thermal and optical systems. Testing was planned for the highest possible level of assembly, and top level system tests for nearly all systems have been performed at this time.

Testing to date has been performed on a mix of LDEF and individual experimenter systems. No electrical or mechanical system level failures attributed to the spaceflight environment have yet been detected. Some low cost electrical components were used successfully, although relays were a continuing problem. Mechanical galling has been observed unexpectedly, but no evidence of cold welding has been identified yet. A working index of observed systems anomalies has been created and will be used to support the tracking and resolution of these effects.

LDEF hardware currently available to the Systems SIG includes most of the LDEF facility systems hardware, and some significant experimenter hardware as well. A series of work packages has been developed for each of several subsystem types where further testing is of critical interest.

The Systems SIG is distributing a regular newsletter to the greater LDEF community in order to maintain coherence in an investigation which is widely scattered both in subject matter and in geography. Circulation of this informal document has quadrupled in its first year.

N91-25085

LDEF ELECTRONIC SYSTEMS: SUCCESSES, FAILURES AND LESSONS

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S113-23
NES-ONLY
11926
P.1

ABSTRACT

Following LDEF retrieval, the Systems SIG participated in an extensive series of tests of various electronic systems, including the NASA-provided data and initiate systems, and some experiment systems. Overall, these were found to have performed remarkably well, even though most were designed and tested under limited budgets and used at least some non-space-qualified components. Several anomalies were observed, however, including a few which resulted in some loss of data. This paper will discuss the post-flight test program objectives and observations, and the "lessons learned" from these examinations. All analyses are not yet complete, but observations to date will be summarized, including the Boeing experiment component studies and failure analysis results related to the Interstellar Gas Experiment. Based upon these observations, suggestions for avoiding similar problems on future programs will be presented.

N91-25086

LDEF MECHANICAL SYSTEMS

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SIG-37
MECH. SYS'T
11937
P.1

ABSTRACT

Following LDEF retrieval, the Systems SIG has been involved in a considerable amount of testing of mechanical hardware flown of LDEF. The primary objectives were to determine the effects of the long term exposure on 1) mechanisms employed both on LDEF or as part of individual experiments, 2) structural components, and 3) fasteners. This paper will present results of testing the following LDEF hardware; LDEF structure, fasteners, trunnions, end support beam, environment exposure control cannisters, motors, and lubricants. A limited discussion of PI test results will be included. "Lessons learned" will be discussed along with the future activities of the System SIG

N91-25087

ON-ORBIT COLDWELDING

NBS ONLY
11928
p.1

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ABSTRACT

Spacecraft mechanisms are required to operate in the space environment for extended periods of time. A significant concern to the spacecraft designer is the possibility of metal-to-metal coldwelding or significant increases in friction. Coldwelding can occur between atomically clean metal surfaces when carefully prepared in a vacuum chamber on Earth. The question is whether coldwelding will occur in on-orbit service conditions. This paper will present the results of the System SIG investigation into whether coldwelding had occurred on any LDEF hardware. The results of a literature search into previous ground based and spacecraft coldwelding experiments along with a review of spacecraft anomalies will also be presented. Results show that even though there have been no documented on-orbit coldwelding related failures, precautions should be taken to ensure that not only does coldwelding not occur in the space environment, but that seizure does not occur in the pre-launch or launch environment.

N91-25088 !

THERMAL CONTROL SURFACES EXPERIMENT (S0069) FLIGHT SYSTEMS PERFORMANCE

S11b-15
ABSTRACT ONLY
11929
P. 1

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ABSTRACT

The Thermal Control Surfaces Experiment (TCSE) was the most complex hardware system aboard the LDEF. The TCSE system consists of a scanning spectroreflectometer that measured test samples mounted on a rotatable carousel assembly. A microprocessor based data system controlled all aspects of TCSE system operation. Power was provided by four primary batteries. Flight measurement and housekeeping data were stored on a tape recorder for post-flight analysis. The TCSE is a microcosm of complex electro-optical payloads being developed by NASA, DoD and the aerospace community. The TCSE provides valuable data on the performance of these systems in space.

The TCSE flight system and its excellent performance on the LDEF mission will be described. A few operational anomalies were encountered and will be discussed. Initial post-flight tests show that the TCSE system remains functional although some degradation in the optical measurements were observed. The results of these tests will also be presented.

Experiment No. S0069

N91-25089

POST FLIGHT SYSTEM ANALYSIS OF FRECOPA (A 0138)

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S117-31
ABS ONLY
11930
p. 1

ABSTRACT

The unexpected duration for the flight of the Long Duration Exposure Facility (LDEF) Satellite, conducted CNES to create a special investigation group in order to analyse all the materials and systems which compose the FRench COoperative PAyload (FRECOPA) except the experiments especially prepared for the flight.

The FRECOPA tray was on the trailing face (V-) of the LDEF and protected from the atomic oxygen flux during all the flight. However the solar irradiation was very important with solar flux quite perpendicular to the experiment once an orbit. We had also a good vacuum environment.

The objectives are to test the effects of the combined space environment on materials and componants like : structure, thermal control coatings and blankets, electronic unit, motors, mechanical fixtures.

When the satellite returned to KSC, a visual inspection showed, the very good behaviour of the materials used and we noted that the three mechanisms to open and close the experiment canisters worked completely. We observed also many impacts of micrometeoroids or space debris on the structure and on the thermal protections.

After FRECOPA has been brought back to Toulouse, we performed many tests in our facilities or in external laboratories :

- working order tests
- mechanical tests (tension)
- optical and electronical microscopy (SEM)
- surface analysis (ESCA, SIMS, RBS, AUGER . . .)
- thermal analysis
- pressure measurements and gas analysis, outgassing tests

The first results show :

- The system (electronic,cinematics and motors) is always in working order and we do not observe any sticking during the opening of the boxes. The vacuum inside is still quite good.
- An important color change for glues, Mylar®, velcros, thermal coatings, plastics straps, base clamps and all parts exposed to solar flux.
- An noticeable erosion of Delrin® (30 µm) and tefloned glass fabric (10 µm).
- Very small variations of mechanical tests results of tefloned fabric, MLI, Nomex® threads, seals, radiation shields, interconnecting harness. For the Mylar® we can't perform tension test because the material is too brittle.
- No important changes in Tg temperature of glues, tefloned fabric, velcro, Delrin® , butyl seals.
- Noticeable variations of thermooptical parameters, specially of tefloned glass fabric and Mylar® in sun exposed areas.

N91-25090

EFFECTS OF ULTRAVACUUM AND SPACE ENVIRONMENT ON CONTACT OHMIC RESISTANCE

(A0 138-11)

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P.1

ABSTRACT

The experiment was aimed at checking compatibility of the aluminium conductors with conventional conductors and contacts under different conditions of manufacturing (mechanical or magnetostrictive crimping) and storage in laboratory or in long-duration space environment.

The electrical characteristics of connections built from nickel-plated conductors and gilded copper contacts have been noted to vary over the duration of the experiment. These variations are unrelated with the crimping or storage conditions or with metal pairing (nickel-plated aluminium/tinned or silvered copper). Such evolutions, even slight, are detrimental to connection quality.

The same observations hold for some like connections subjected to long-duration thermal cycles (15000 cycles from -100 C to +130 C). Therefore, work on aluminium technology has been reoriented toward a silvered aluminium conductor/golded aluminium contact solution. The first evaluation tests performed according to this definition have yielded satisfactory results.

N91-25091

MICROWELDING OF VARIOUS METALLIC MATERIALS UNDER ULTRAVACUUM
(A0 138-10)

S119-37
ARS ONLY
11932
P.1

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ABSTRACT

The first finding from A0 138-10 is that no cold welding ever occurred, and no microweld affected even the reference (i.e. presumably microweld prone) pairs of metals consisting of gold, silver and chromium.
The scientific disappointment from these results must be tempered by the notion of a static A0 138-10 experiment reflecting the passive character of the global LDEF flight.
Cold-weldind has been hitherto theorized as arising from peeling of the earthly-created oxide layer in such environment as prevents such layer from growing any more.
In fact, such stripping of the oxide layer supposes relative motion of the contacting materials. Failing such motion, as in our case, oxidation will preserve its integrity and continue to prevent microwelding.

More bewildering is the non-microwelding of the reference pairs, contrary to common admission, so far, that the enormous diffusiveness and very low oxydation rate of metals like gold, silver and chromium (hence the shine or glitter) was as sure road to microwelding. Furthermore, solubility between the contacting washers was all the more expectable with like materials.
High diffusiveness ans solubility, which seemed so far to rule out use of gold, silver and chromiumin spaceborne mechanisms, even static ones, have just been proved by the A0 138-10 experiment not to induce any microwelds when there is no relative motion of parts.

Even though A0 138-10 failed scientific expectations, as did the LDEF structure with cold welding, the positive, functional aspect to be borne in mind is the safe operation of single-shot (appendage-releasing and/or latching) mechanisms, unhindered by microwelding in space vacuum, as now demonstrated by the statically representative pairs of materials, forgetting the prediction-failing reference pairs.

To preserve space mechanism representativity, even clearly at the expense of vacuum-microwelding, the parts had received none but the routine surface treatments,hence the traces of machining, of chlorine and sodium chloride, and the (damageable) fingerprints. The likelihood of the scientific phenomenon was thus traded off with functional representativity.

Thus, the technological success of the metallic pairs'freedom from any cold welding phenomenon does vindicate the theory for lack of any relative motion of the metallic parts, the oxygen layer grown on earth will not deteriorate, building up a diffusive barrier that limits occurrence of the vaccuum microwelding phenomenon.
A similar, but dynamic experiment could provide highly interesting scientific results as well as new selection criteria for materials.

N91-25092

LONG DURATION EXPOSURE FACILITY (LDEF)
LOW-TEMPERATURE HEAT PIPE EXPERIMENT PACKAGE (HEPP)
POWER SYSTEM RESULTS

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ABSTRACT

This paper presents an overview of a self contained Direct Energy Transfer (DET) Power System which was developed to provide power to the LDEF HEPP Experiment. A brief synopsis of the flight characteristics of the power system will be presented to illustrate the system's capability to function successfully in a Low Earth Orbit (LEO) space environment. The paper discusses the successful space flight operations of the Battery, Solar Arrays and Power System Electronics during the flight period of almost 6 years, or approximately 32,000 LEO cycles. Future papers will present results from post flight characterization and Destructive Physical Analysis (DPA) performed to evaluate the internal physical properties of the Power System components.

Experiment No. S1001

OTHERS

N91-25093

RESULTS OF THE TTF-TCNQ- AND THE CALCIUM CARBONATE-CRYSTALLIZATION ON THE LONG DURATION EXPOSURE FACILITY.

S21-76
NES 2014
11934
p.1

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Experiment A0139A on the LDEF carried 4 large containers (volume 1 - 2 liters each) into orbit 5 years with crystal growth solutions for Lead Sulphide, Calcium Carbonate, and TTF-TCNQ. The facility was in excellent condition after the long orbital stay; and although the temperature data was lost, the experiment programme had been working, since the valves in all containers had been opened. All 4 experiments produced crystals, however af varying quality. The Calcium Carbonate crystals had the best appearence. The TTF-TCNQ crystals were packed together near the valve openings of the container. When taken apart, the single crystals showed some unusual morphological properties.

X-ray investigations (Laue back-reflection and -transmission diagrammes) as well as conductivity measurements (4-point probe) on long duration space grown TTF-TCNQ crystals will be presented, and pictures of the Calcium Carbonate crystals will be shown. Comparison will be made with our previous space solution growth experiments on the European Spacelab Mission and the Apollo-Soyuz Test Project. The TTF-TCNQ crystals are no longer of the highest scientific interest, so this activity has been terminated by us. Instead the interest in ESA is focussed on the Calcium Carbonate- and the Calcium Phosphate- crystallizations.

Experiment No. A0139A

N91-25094

SEEDS IN SPACE EXPERIMENT RESULTS

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Two million seeds of 120 different varieties representing 106 species, 97 genera and 55 plant families were flown aboard the Long Duration Exposure Facility (LDEF). The seed were housed on the Space Exposed Experiment Developed for Students (SEEDS) tray in the sealed canister number 6 and in two small vented canisters.. The tray was in the F-2 position. The seed were germinated and the germination rates and development of the resulting plants compared to the control seed that stayed in Park Seed's seed storage facility.

The initial results are presented in the paper. There was a better survival rate in the sealed canister in space than in the storage facility at Park Seed. At least some of the seed in each of the vented canisters survived the exposure to vacuum for almost six years. The number of observed apparent mutations was very low. This seed was also shared with professional plant scientist for additional research.

Experiment No. P0004-1

N91-25095

SPACE EXPOSED EXPERIMENT DEVELOPED FOR STUDENTS (SEEDS) P-0004-2

S123-51
REC. ONLY
11936
1.1

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This cooperative endeavor of NASA Headquarters, the NASA Langley Research Center, and the George W. Park Seed Company, resulted in the distribution, by the end of March, 1990, of approximately 132,000 SEEDS kits to 64,000 teachers representing 40,000 classrooms and 3.3 million kindergarten through university students. Kits were sent to every state, as well as 30 foreign countries. Preliminary radiation data indicates that layer A received 725 rads, while layer D received 350 rads. Germination rate was reported to be 73.8 % for space-exposed seeds and 70.3% for Earth-based control seeds. Tests conducted within the first six months after retrieval indicated space-exposed seeds germinated in an average of 8.0 days, while Earth-based control seeds' average germination rate was 8.3 days. Some mutations (assumed to be radiation induced) reported by students and Park Seed include plants that added a leaf instead of the usual flower at the end of the flower frond and fruit produced from a flower with a variegated calyx bore seeds producing albino plants, while fruit from a flower with a green calyx from the same plant bore seeds producing green plants.

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P.1

FIRST BIOLOGICAL AND DOSIMETRIC RESULTS OF THE FREE FLYER BIOSTACK EXPERIMENT A0015 ON LDEF

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ABSTRACT

The main objectives of the Biostack experiment are to study the effectiveness of the structured components of the cosmic radiation to bacterial spores, plant seeds and animal cysts for a long-duration spaceflight and to get dosimetric data such as particle fluences and spectra and total doses for the LDEF orbit. The configuration of the experiment packages allows to localize the trajectory of the particles in each biological layer and to correlate the potential biological impairment or injury with the physical characteristics of the responsible particle.

Although the Biostack experiment was designed for a long-duration flight of only 9 months, most of the biological systems show a high hatching or germination rate. Some of the first observations are an increase of the mutation rate of embryonic lethals in the second generation of Arabidopsis seeds, somatic mutations and a reduction of growth rates of corn plants and a reduction of life span of Artemia salina shrimps. The different passive detector systems are also in a good shape and give access to a proper dosimetric analysis.

This paper will summarize the results obtained so far and will show some aspects of the future analysis.

N91-25097

RETRIEVABLE PAYLOAD CARRIER (RPC)
--NEXT GENERATION LONG DURATION EXPOSURE FACILITY--

S125-18
ACS ONLY
11938
P.1

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ABSTRACT

This paper describes the Retrievable Payload Carrier (RPC), which is a multi-experiment, free-flyer spacecraft being privately developed to make in-space experimentation more accessible and economically feasible for research and development organizations. The carrier concept was derived from NASA's highly successful and flight-proven Long Duration Exposure Facility (LDEF). The LDEF capabilities have been enhanced to meet new customer requirements. This reusable payload carrier is planned for launch and retrieval by the space shuttle on a regular basis. The RPC's compact design will facilitate flexible manifesting of the shuttle cargo bay space, thereby permitting timely launches and retrievals. The vehicle is designed so that either the entire carrier can be retrieved from orbit, or individual experiment pallets can be removed and replaced in orbit. This will give customers even greater control over their experiment recoveries. A fully operational RPC System consists of: 1) a carrier spacecraft; 2) a ground control station for communication with customer payloads and the carrier; 3) a ground processing facility to provide refurbishment, final checkout, and integration of customer payloads and the carrier; and 4) the personnel required to support both the development and operational phases of the program. Customer payloads will fly 6-18 month missions, or longer, as required. Spreading launch, operations, and retrieval costs over multiple experimental payloads results in minimized customer costs. The RPC Program's initial objective is to operate a simple carrier system which meets basic customer service needs.

N91-25098

SURVIVAL OF EPIPHYTIC BACTERIA FROM SEED STORED ON THE LONG DURATION EXPOSURE FACILITY (LDEF)

5126-51
ALOS ONLY
11939
p.1

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ABSTRACT

Microbial contamination in American spacecraft has previously been documented (Appl. Microbiol., 1973, 26:804-813 and Ann. Rev. Microbiol., 1974, 28:121-137). However, potential risks to plants and humans in future space-based controlled ecological life support systems (CELSS) have yet to be addressed directly. The current study was designed to determine the survival of microorganisms exposed to the relatively harsh conditions found in low Earth orbit (LEO).

Seed of corn, sunflower, canteloupe, zucchini, bean, pea, and pumpkin cultivars were packaged in two 18 x 2.5 cm aluminum tubes; wall thickness of each tube was 1.33 mm. One seed tube was attached to payload M0006, tray C-2; a second tube was stored at room temperature in a lab on Earth. Five lithium fluoride thermoluminescent dosimetry wafers (TLD-100 wafers) were placed in each aluminum tube. The total mean dosages for flight and ground-control TLD wafers were 210.2 and 0.9 rads, respectively.

Seed were washed for 2 hrs in a phosphate buffered saline solution. Bacteria were isolated by plating samples of the seed-washings onto dilute tryptic soy agar. Pure isolates of morphologically distinct bacteria were obtained by standard microbiological procedures. Bacteria were grouped according to colony-type and preliminary identification was completed using a fatty-acid analysis system (Can. J. Microbiol., 1986 32:796-800). *Bacillus* spp. were the primary microorganisms that survived on seed during the experiment. Bacterial diversity and relative abundance were similar for the ground and flight seed. *Bacillus subtilus, B. pumilus, B. licheniformis, B. polymyxa, B. megaterium,* and *B. pabuli* were isolated most frequently. Members of the genera *Kurthia, Listeria, Micrococcus,* and *Arthrobacter* were also isolated from flight and ground-control seed. Results support the hypothesis that terrestrial microorganisms can survive long periods of time in the relatively harsh LEO environment.

Experiment number M0006

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16. Abstract

This volume is a compilation of abstracts submitted to the First Long Duration Exposure Facility (LDEF) Post-Retrieval Symposium. The abstracts represent the preliminary data analysis of the 57 experiments flown on the LDEF. The experiments include materials, coatings, thermal systems, power and propulsion, science (cosmic ray, interstellar gas, heavy ions, micrometeoroid, etc.) and electronics and optics.

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